CENTER FOR ENERGY AND PROCESSES - CEP

Evaluation of the Potential Impact of Emissions of HFC-134a from Nonprofessional Servicing of Motor Vehicle Air Conditioning Systems

CARB Agreement No. 06-341

ARMINES Reference 70890

Draft Final Report

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Prepared for the California Air Resources Board and the California Environmental Protection Agency

July 2008

Acknowledgements

The following people have participated in the report
Aline GARNIER for documentation
Simon CLODIC and Martin LANSARD for surveys in California

This report was submitted in fulfillment of
ARB Agreement No. 06-341,
"Evaluation of the Potential Impact of Emissions of HFC-134a From Non Professional Servicing of Motor Vehicle Air Conditioning Systems
by ARMINES under the partial sponsorship of the California Air Resources Board.
Work was completed as of June 30, 2008.

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Abstract

This report is based on two field studies and several measurements of leak flow rates of mobile vehicle air-conditioning (MVAC) components and systems. The first field study has been dedicated to the analysis of the operation mode of about 50 Do-It-Yourselfers (DIYers) making the recharge of a MVAC system with one or several small cans. This field study has allowed evaluating R-134a emissions related to servicing by those DIYers. The second field study has been dedicated to the analysis of the operating mode by professionals when the MVAC system of a vehicle is significantly undercharged. The diagnosis, the leak search, the recovery of refrigerant as well as the recharge of the system are described and show significant differences of practices among professionals. Costs of professional servicing as well as costs of small cans have been established. The laboratory tests have shown that the typical leak flow rate of the MVAC systems of the five most used cars in California are of the same order of magnitude as the leak flow rates of European and Japanese cars. The overall environmental impact of refrigerant emissions due to the use of small cans has been estimated based on small can sales in California and emission rates as measured by the field tests.

EXECUTIVE SUMMARY

Based on available data indicating that about 2 million small cans of R-134a are sold every year in California, and making the assumption that 80% of those cans are used by DIYers, the remaining 20% being use by professional technicians, emissions of refrigerant due to servicing with small cans, expressed in equivalent CO_2, are estimated in the range of 267,000 tonnes of CO_2 equivalent.

a) Regular leaks and servicing

The annual leak flow rates (LFRs) of MVAC systems of the five most sold cars in California have been measured following the methodology defined in the EU regulation 706/2007 [EUR07] (Section 1). The initial annual leak flow rates of those five MVAC systems are of the same order of magnitude as those measured on European or Japanese cars. The average annual LFR of new systems is in the range of **10 g/yr ± 4** and possibly slightly higher for some double evaporator systems.

Tests made on MVAC system test bench running continuously during 7 hours with a leak in the range of 1.5 g/min. show that about 50% of the refrigerant charge has to be lost before possible diagnosis of insufficient cooling (Section 4.1.1).

Recommendation: No servicing is needed on the refrigerating circuit of MVAC systems during at least the first 7 years, except if no cooling is acknowledged because the "regular" leaks are low. Complementary research work is needed to analyze the leak tightness degradation of compressor shaft seals due to several years of operation, in order to understand when MVAC systems become significantly more emissive.

b) **Emissions of refrigerant by DIYers when charging MVAC with small cans**

For the studied sample of DIYers: 2/3 of the refrigerant has been charged in the MVAC system, 1/3 has been emitted.

The main drawbacks associated with non-professional servicing are:

- Recharge without knowledge of remaining refrigerant and of the reference charge
- Recharge without leak search
- Recharge without recovery
- Wrong recommendations written on the can and the pressure gauge of the charging kit.

c) Professional servicing

The possible added values of professional servicing are:

- correct diagnosis of failure
- efficient leak search
- use of recovery and recharge (R&R) machine
- capability of repair.

Diagnosis: The diagnosis of professionals is usually good when a minimum refrigerant quantity remains in the MVAC system.

Leak search: Only a little more than 50% of the sample of professionals have performed leak search. The most used method has been the use of dye.

It has to be noted that, for the sample of professionals, none of the leak search with electronic leak detector has been successful (even if one slow leak was existing at the expansion valve), neither with other methods.

The lesson learnt by professional servicing on the necessary time lag between charging the dye and making a possible diagnosis of leak is confirmed by laboratory tests.

Use of recovery and recharge machine: About 2/3 of professionals have used automated Recovery, evacuation and Recharge machine, which are essential for limiting refrigerant emissions during servicing, providing that the recovery is performed down to 4 psi abs.
Nevertheless, even with automated machines, few professionals verify the original charge of refrigerant required by the car manufacturer.

The most important conclusion is that when professionals use R&R equipment, emissions are drastically reduced, in the range of 20 g per operation providing that the low pressure threshold of the recovery machine is set at 4 Psi abs.

Recommendations:

- Systematic leak search before recovery when the saturating pressure is measured in the MVAC system
- Systematic use of R&R machines
- No recharge without verification of the original charge
- Stick a tag in the under hood indicating the recovery and recharge date.

d) Costs of professional and non professional servicing

For simple recharge without leak search the cost of recharge is multiplied by a factor 3 to 4 when comparing the cost a small can and the cost of recharge with a small can by a professional (20 $ compared to 80 $). When using a recovery machine with or without leak search the average cost is 120 $.

e) Servicing MVAC by Do-it-yourselfers without small cans

When comparing the operation mode of a DIYer connecting a small can:

- to the charging kit
- then to the low pressure service valve
- shaking the can with the AC on for a proper recharge
- feeling that the can is empty

and what has to be done for using an automated R&R machine:

- connection of the blue hose to the low pressure service valve
- connection of the red hose to the high pressure service valve
- push the button, and
- come back half an hour after

the simplicity is clearly for using an automated machine.

It is possible to discontinue the use of small cans, but still make possible for DIYers to recharge MVAC system by themselves through renting a R&R machine at auto parts dealers. The renting system can be promoted similarly to the one for inflating tires: the end-user does not buy an air compressor to inflate tires of his car.
Providing that UV dye is charged when the car is manufactured, then there is no other constraint for DIYers than renting a UV lamp to the auto part dealer. If UV dye is not charged, it has to be done either by a professional or by using a small can with dye.

Recommendations: if non professional servicing were authorized:

- The operating mode has to be completely changed: no more small cans for recharge but R&R machine to be rented by non professional at auto parts stores
- In order to make leak detection possible, UV dye should be charged initially at the manufacturing site and UV lamp to be rented at the auto parts stores
- In the intermediate period, dye charged either by professional or by non professional will give easiness to the leak detection process.

Introduction

The main objective of the program is to develop experimental data in order to better estimate emissions of HFC-134a due to non-professional servicing of MVAC systems. The overall working program is divided in six tasks and presented as follows:

- Measurements of initial leak flow rate (LFR) of the five most used MVAC systems in California
- Analysis of current recharge by non-professionals in California
- Analysis of current leak search and recharge by professional servicing in California
- Laboratory tests simulating non-professional operating modes in California
- Evaluation of the sales of HFC-134a disposable cans in California
- Recovery of samples of disposable cans after usage by non-professionals in California

The field study shows immediately that the cans are empty when put to the trash and so there is no interest in Task 6, because possible recovery of left refrigerant in disposed cans has no purpose. So the initial Task 6 has been replaced by the analysis of leaks from cans and from the charging kits. Moreover a first comparative analysis of the sensitivity of three leak methods has been carried out.

New results have been gained from the two field studies that have never been carried out before. The realistic conditions of MVAC servicing either by Do-It-Yourselfers (DIYers) or by professional technicians lead to draw conclusions on refrigerant emissions due to servicing and have also permitted to define possible measures leading to lower significantly level of emissions for servicing.

For measurements of LFRs of MVAC systems a proven methodology has been used corresponding to the European Regulation 706/2007 [EUR07], which is based on measurements of LFRs of a fleet of 40 vehicles, a laboratory study made on 40 MVAC systems corresponding to the 40 vehicles, and measurements on 100 components in order to demonstrate that the sum of LFRs of components equals the overall LFR of the MVAC system.

For the analysis of recharge by non-professionals, the main and perhaps the only previous study has been carried out by Perrin Quarles Associates Inc. fort the US EPA [QUA07] associated with a review of the report by experts. The report describes charges made with small cans and charges made by 30-lb cylinder, saying that one is typical of DIYers and the other one of professionals. The study has been carried out in a University and one of the main drawbacks of the methodology, as underlined by the reviewers, is that the system before charge is completely evacuated, which changes significantly the conditions of recharge either by small cans or by cylinders. The difference of pressure between an evacuated and an under pressure cylinder or can creates a driving force that is not reflecting the reality of recharge when refrigerant remains, which is typical of under charge systems delivering non sufficient cooling. Nevertheless, the report is interesting description of possible ways of using small cans in the upright position or in the upside down position or with rapid shaking of the can in order to charge in two-phase flow. Tests have been done by students in a laboratory of the university (UTI in Avondale, AZ). This report has been carefully studied before the CEP performed its study in California on a sample of small can users.

For professional servicing, as far as we know, it is the first time that a field survey, describing the current practices of technicians in different types of garages, has been carried out. The only literature available is the recommendations coming from the MACS Service Reports [MAC06].

1. Measurements of initial leak flow rate (LFR) of the five most used MVAC systems in California

1.1 Test method

The test bench dedicated to the leak flow rate measurement of the whole AC system has been developed by the Center for Energy and Processes CEP [ACE05]. The leak measurements are performed in accordance with the European directive 2006/40/EG [EUD06]. The test procedure detailed by the European regulation 706/2007 [EUR07] is described hereafter.

The MVAC system (see Photo 1.1) is first mounted, evacuated, and charged with the nominal manufacturer refrigerant charge (±1 gram) and then installed inside the mini-shed.

According to the specifications given by [EUR07], the pre-conditioning is performed at 50°C during 10 days. Thereafter, the mini-shed is rinsed and tests are carried out at 40°C. For the sake of establishing a regression law on the five U.S. MVAC systems, three temperatures are successively controlled in order to measure the three corresponding leak flow rates (LFRs).

Photo 1.1: Installation of MVAC system in mini-shed.

An infrared photo-acoustic spectroscope, having a detection limit of 15 ppb, measures the refrigerant accumulated inside the mini-shed. The mass flow rate is the product of molar mass and the derivative of the number of moles of HFC-134a along the time in a tight volume (the test chamber). The perfect gas law is used to take into account the small variations of pressure and temperature inside the test chamber. According to Equation (1.2), the following parameters need to be determined for the leak flow rate calculation: the accumulation volume of the test chamber V_{accum}, the temperature T_{amb} and the pressure P_{amb} inside the test chamber, and the evolution of concentration along the time.

The method used to determine the LFR is based on Equation (1.1).

$$\dot{m}_{HFC-134a} = M_{HFC-134a} \cdot \frac{\partial n_{HFC-134a}}{\partial t} \tag{1.1}$$

Where,

$$n_{HFC-134a} = n_{total} \cdot C = \frac{P_{amb} \cdot V_{accum}}{R \cdot T_{amb}} \cdot C \tag{1.2}$$

$\dot{m}_{HFC-134a}$	HFC-134a mass flow rate ($g.s^{-1}$)
$M_{HFC-134a}$	HFC-134a molar mass (102 $g.mol^{-1}$)
$n_{HFC-134a}$	Number of mole (mol)
t	Time (s)
C	Refrigerant concentration (ppm)
P_{amb}	Ambient pressure (Pa)
V_{accum}	Accumulation volume (m^3)
R	Gas constant (8.314×10^3 kJ $kmol^{-1}$ K^{-1})
T_{amb}	Ambient temperature (K)

1.2 Tests results

All five MVAC systems, referenced in this report as systems A, B, C, D, and E, have been bought at after-service market of each brand name and have been mounted at the CEP according to the specifications of the manufacturer. All those systems are composed of brand new components and so their LFRs are representative of so-called regular leaks coming from new systems. The ACEA study, carried out by the CEP in 2005 [ACE05], has been performed similarly; the 40 systems that have been studied were composed of brand new components. Characteristics, results of tests, and variation of leak flow rate depending on outdoor temperatures are presented for each system in Sections 1.2.1 to 1.2.5. Raw data of measurements for each of the five systems are presented in five appendices at the end of Section 1.

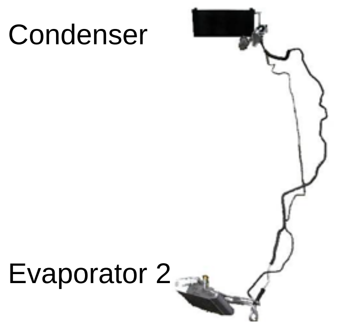
1.2.1 MVAC system A

System specifications

Table 1.1: System specifications.

Reference	System A
Type	SUV
Motorization	/
Vintage	2002-2004
MVAC system	Dual evaporator
Nominal refrigerant charge	1400 g

System design



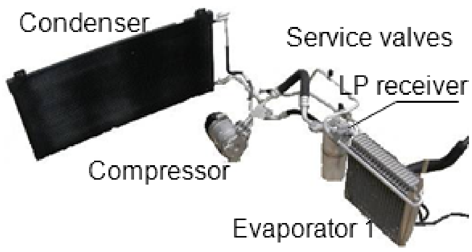


Photo 1.2: Assembled MVAC system A.

Table 1.2: List of components.

Components	Numbers of components	Details
Compressor	1	
Condenser	1	
LP receiver	1	Located on the outlet of the evaporator 1
Evaporator	2	
Expansion valve	2	Evaporator 1: Orifice tube Evaporator 2: TXV
Liquid line	3	
Suction line	2	
HP service valve	1	Located on the discharge line
LP service valve	2	Located on the liquid line 1 & 2
HP sensor	1	Located on the discharge line
LP sensor	1	Located on the LP receiver

__Leak flow rate calculation__

Table 1.3 summarizes the MVAC system A leak flow rates for three different temperatures.

Figure 1.1 illustrates the evolution of leak flow rate as a function of pressure.

Table 1.3: LFRs of MVAC system A.

T (°C)	Saturation Pressure (kPa)	LFR (g/yr)
30	770	13.0 ± 0.8
40	1017	25.3 ± 1.5
50	1318	44.8 ± 2.7

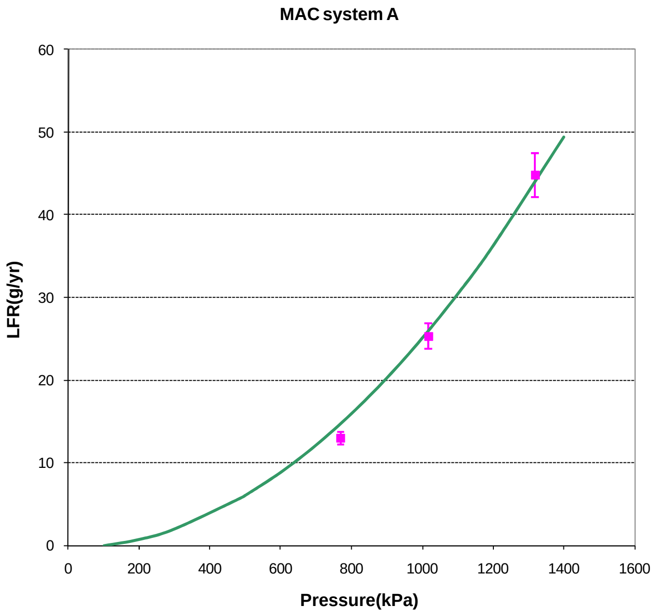


Figure 1.1: LFRs and regression curve.

Using the method of least squares, a good agreement between the measured values and the regression curve of binomial expression has been verified and is expressed by Equation 1.3.

$$LFR = k(P_{upstream}^2 - P_{downstream}^2) \qquad (1.3)$$

Where $P_{upstream}$ is the R-134a pressure inside the system (which is upstream the possible leak passage and $P_{downstream}$ is the atmospheric pressure.

The objective of this approximation is to find a general approach for MVAC system leakage behavior as a function of pressure, which will be used for leak flow rate prediction at a required temperature. Once the equation parameter K is determined, the MVAC leak flow rate is calculated at the corresponding temperature for each zone.

This semi-empirical formula takes into account a large number of tests (more than 1000) performed by the CEP from 1995 to 2008 showing that, for MVAC systems, the dominant leak flow rates are coming from the compressor shaft seal and fittings. They represent 70 to 80% of emissions of the MVAC system. Due to the level of pressure, the flow regime is the viscous one and so the Darcy law is applicable, leading to the structure of Equation 1.3. Nevertheless permeability of elastomers composing the hoses of the MVAC system follows permeability laws depending on pressure and temperature. Even if permeability is a linear function of pressure, the pressure variation of a MVAC system for temperatures varying from 0 to 50°C follows the saturating pressure law, known as the Antoine law (logP as a function of -1/T). This saturating pressure law leads to very small differentiation of the leak flow rate depending on permeability compared to leak flow rate through micro-channels. A much more detailed explanation is given in [YU08].

Considering the population for the ten Californian zones (in fact only eight are known, because no data on population are available for Bakersfield and Long Beach), the LFR is determined as a function of the temperature and so the saturation pressure, see Table 1.4. Annual LFR of System A varies from 4.2 to 7.9 g/yr depending on the climatic zone, and the average value based on the population lead to an annual average value of 6.3 g/yr for California. This result is indicated both in Table 1.4 and in Figure 1.2.

Example: taking the Arcata zone (see Table 1.4), the mean temperature of 10.4°C corresponds to the saturation pressure of 420 kPa. Using Equation 1.3, a leak flow rate value of 4.2 g/yr ($2.536 \times 10^{-5} * (420^2 - 101^2)$) is obtained.

Table 1.4: Determination of the annual LFR of MVAC system A taking into account CA population.

	Arcata	Bakersfield	Daggett	Fresno	Long Beach	Los Angeles	Sacramento	San Diego	San Francisco	Santa Maria	Total
Annual mean T(°C)	10.4	18.5	19.8	17.1	17.2	16.7	15.2	17.6	13.1	12.9	
Saturation Pressure(kPa)	420	546	568	522	523	516	492	530	459	456	
					K= 2.536E-05						
LFR(g/yr)	4.2	7.3	7.9	6.7	6.7	6.5	5.9	6.9	5.1	5.0	
Population	790525		4669274	2962948		12901515	3443421	2933929	5966569	2173073	35841254
% Population	2.2%		13.0%	8.3%		36.0%	9.6%	8.2%	16.6%	6.1%	100%
LFR%	0.1		1.0	0.5		2.3	0.6	0.6	0.8	0.3	**6.3**

Note: lines 1 and 2 indicate respectively annual mean temperature and annual saturating pressure.

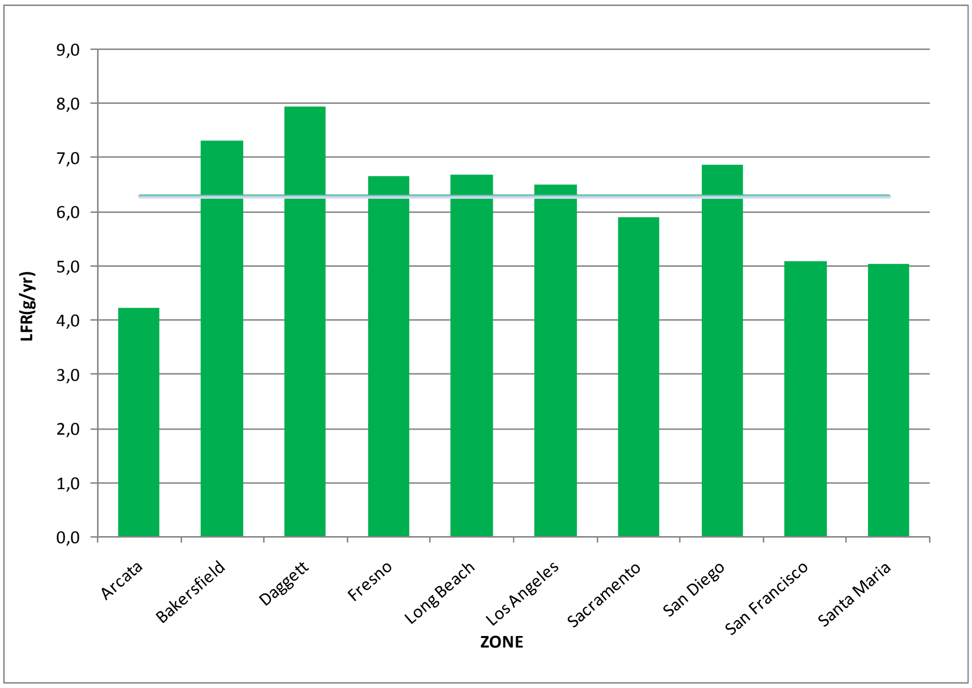


Figure 1.2: LFR variations depending on the average temperature of the 10 climatic zones and average value (line) for California.

1.2.2 MVAC system B

System specifications

Table 1.5: System specifications.

Brand	MVAC system B
Type	Van
Motorization	3.3 l SMPI
Vintage	2005
MVAC system	Dual evaporator
Nominal refrigerant charge	1080 g

System design

Photo 1.3: Assembled MVAC system B.

Table 1.6: List of components.

Components	Numbers of components	Details
Compressor	1	
Condenser	1	
HP liquid receiver	1	Located on the principal liquid line
Evaporator	2	
Expansion valve	2	Thermal expansion valve
Liquid line	5	
Suction line	4	
HP service valve	1	Located on the main liquid line
LP service valve	1	Located on the main suction line
HP sensor	1	Located on the main liquid line after the HP receiver

Leak flow rate calculation

Table 1.7: LFRs of MVAC system B.

T (°C)	Saturation Pressure (kPa)	LFR (g/yr)
30	770	19.6 ± 1.2
40	1017	33.0 ± 2.0
50	1318	59.4 ± 3.6

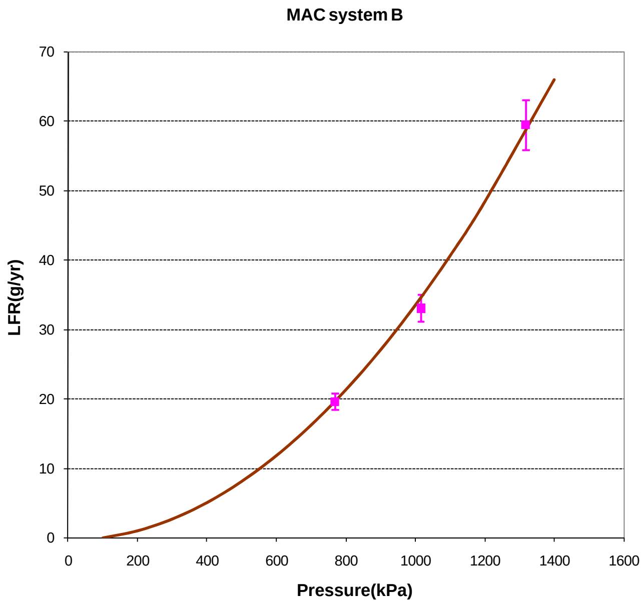


Figure 1.3: LFRs and regression curve of MVAC system B.

Table 1.8: Determination of the annual LFR of MVAC system B taking into account CA population.

	Arcata	Bakersfield	Daggett	Fresno	Long Beach	Los Angeles	Sacramento	San Diego	San Francisco	Santa Maria	Total
Annual mean T(°C)	10.4	18.5	19.8	17.1	17.2	16.7	15.2	17.6	13.1	12.9	
Saturation Pressure(kPa)	420	546	568	522	523	516	492	530	459	456	
K= 3.382E-05											
LFR(g/yr)	5.6	9.7	10.6	8.9	8.9	8.7	7.8	9.2	6.8	6.7	
Population	790525		4669274	2962948		12901515	3443421	2933929	5966569	2173073	35841254
% Population	2.2%		13.0%	8.3%		36.0%	9.6%	8.2%	16.6%	6.1%	100%
LFR%	0.1		1.4	0.7		3.1	0.8	0.7	1.1	0.4	**8.4**

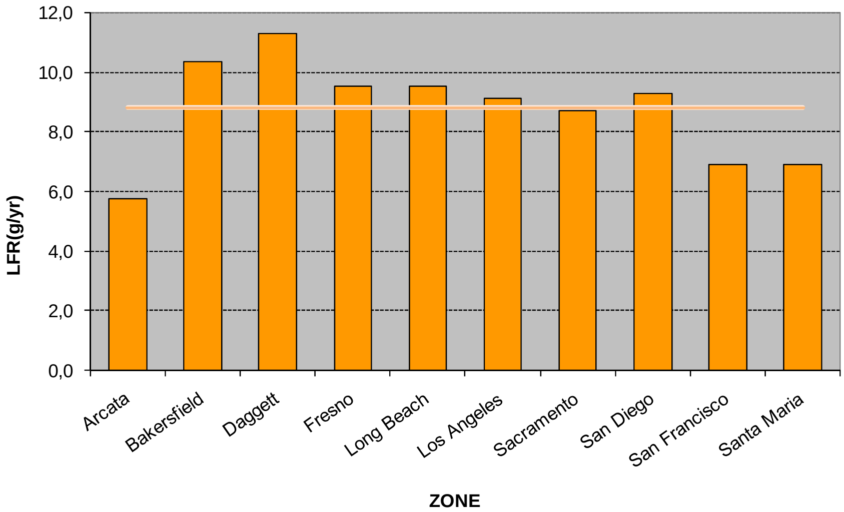


Figure 1.4: LFR variations depending on the average temperature of the 10 climatic zones and average value (line) for California.

The average value for system B in California is 8.4 g/yr.

1.2.3 MVAC system C

System specifications

Table 1.9: System specifications.

Brand	MVAC system C
Type	Pickup
Motorization	5.4 l
Vintage	2007
MVAC system	Single evaporator
Nominal refrigerant charge	940 g

System design

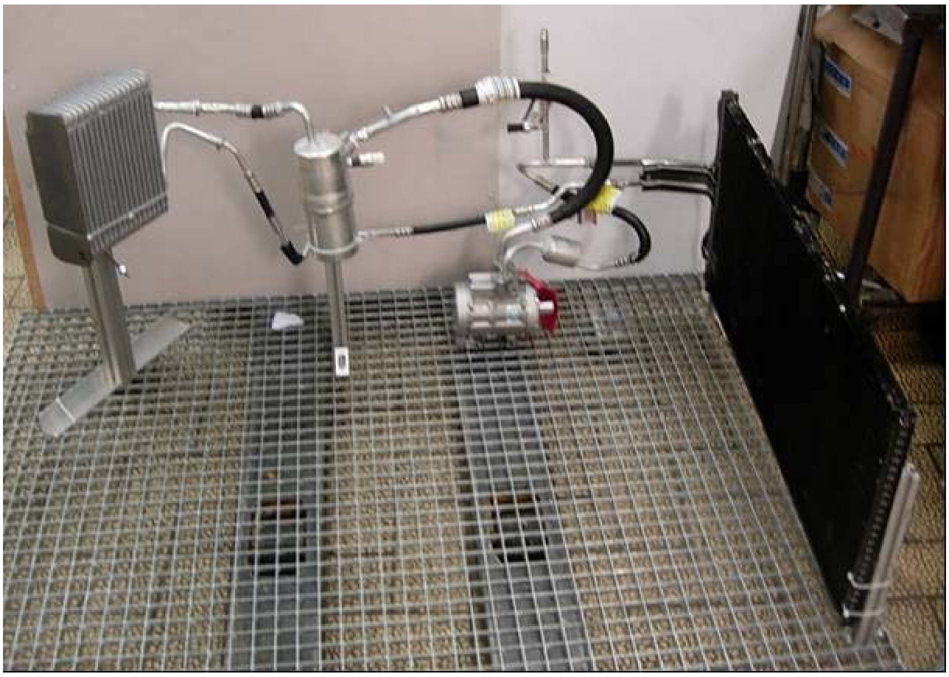


Photo 1.4: Assembled MVAC system C.

Table 1.10: List of components.

Components	Numbers of components	Details
Compressor	1	
Condenser	1	
Evaporator	1	
LP receiver	1	
Expansion valve	1	Orifice tube
Discharge line	1	
Liquid line	1	
Suction line	2	
HP service valve	1	Located on the discharge line
LP service valve	1	Located on the suction line
HP sensor	1	Located on the suction line
LP sensor	1	Located on the LP receiver

Leak flow rate calculation

Table 1.11: LFRs of MVAC system C.

T (°C)	Saturation Pressure (kPa)	LFR (g/yr)
30	770	13.9 ± 0.8
40	1017	21.7 ± 1.3
50	1318	35.4 ± 2.1

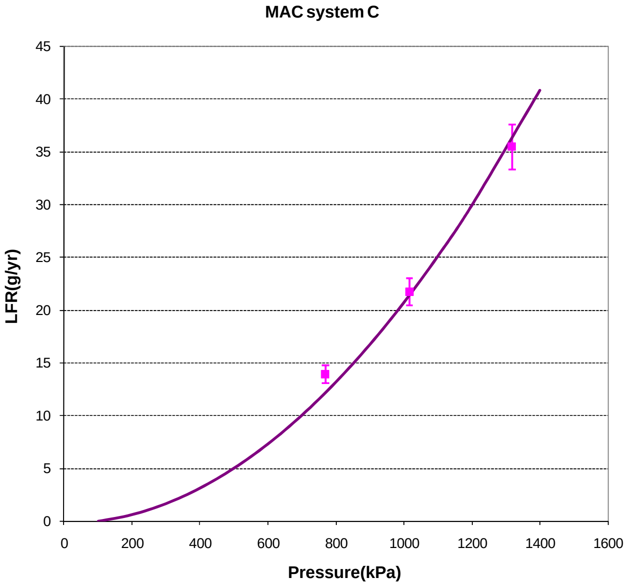


Figure 1.5: LFRs and regression curve of MVAC system C.

Table 1.12: Determination of the annual LFR of MVAC system B taking into account CA population.

	Arcata	Bakersfield	Daggett	Fresno	Long Beach	Los Angeles	Sacramento	San Diego	San Francisco	Santa Maria	Total
Annual mean T(°C)	10.4	18.5	19.8	17.1	17.2	16.7	15.2	17.6	13.1	12.9	
Saturation Pressure(kPa)	420	546	568	522	523	516	492	530	459	456	
K= 2.093E-05											
LFR(g/yr)	3.5	6.0	6.5	5.5	5.5	5.4	4.9	5.7	4.2	4.1	
Population	790525		4669274	2962948		12901515	3443421	2933929	5966569	2173073	35841254
% Population	2.2%		13.0%	8.3%		36.0%	9.6%	8.2%	16.6%	6.1%	100%
LFR%	0.1		0.9	0.5		1.9	0.5	0.5	0.7	0.3	**5.2**

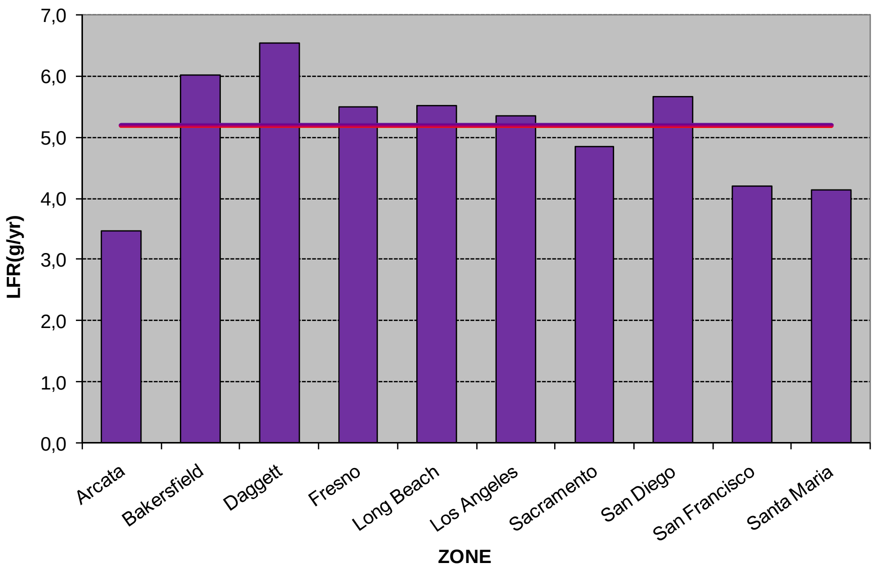


Figure 1.6: LFR variations depending on the average temperature of the 10 climatic zones and average value (line) for California.

The average value for system C in California is 5.2 g/yr.

1.2.4 MVAC system D

System specifications

Table 1.13: System specifications.

Brand	MVAC system D
Type	Family car
Motorization	2.4 l
Vintage	2006
MVAC system	Single evaporator
Nominal refrigerant charge	650 g

System design

Photo 1.5: Assembled MVAC system D.

Table 1.14: List of components.

Components	Numbers of components	Numbers of fittings
Compressor	1	
Condenser	1	
Evaporator	1	
Expansion valve	1	Thermal expansion valve
LP liquid receiver	1	
Liquid line	3	
Suction line	2	
HP service valve	1	Located on the liquid line 2
LP service valve	1	Located on the suction line 1
HP sensor	1	Located on the liquid line 2

Leak flow rate calculation

Table 1.15: LFRs of MVAC system D.

T (°C)	Saturation Pressure (kPa)	LFR (g/yr)
30	770	28.4 ± 1.7
40	1017	49.1 ± 2.9
50	1318	95.3 ± 5.7

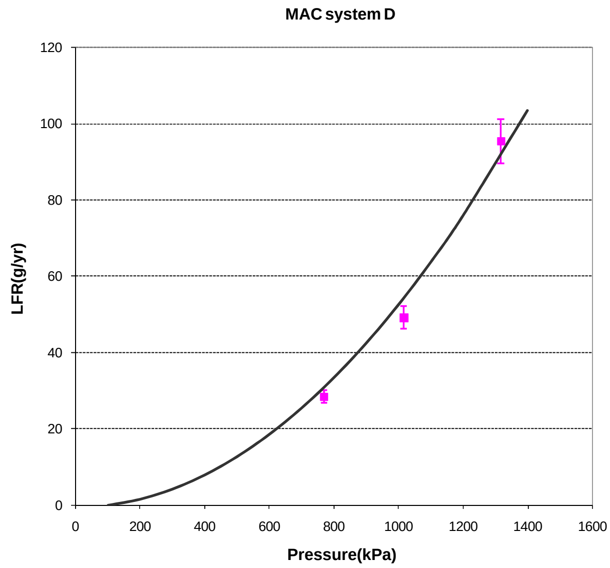


Figure 1.7: LFRs and regression curve of MVAC system D.

Table 1.16: Determination of the annual LFR of MVAC system B taking into account CA population.

	Arcata	Bakers field	Daggett	Fresno	Long Beach	Los Angeles	Sacramento	San Diego	San Francisco	Santa Maria	Total
Annual mean T(°C)	10.4	18.5	19.8	17.1	17.2	16.7	15.2	17.6	13.1	12.9	
Saturation Pressure(kPa)	420	546	568	522	523	516	492	530	459	456	
K= 5.29E-05											
LFR(g/yr)	8.8	15.2	16.5	13.9	13.9	13.6	12.3	14.3	10.6	10.5	
Population	790525		4669274	2962948		12901515	3443421	3E+06	5966569	2173073	35841254
% Population	2.2%		13.0%	8.3%		36.0%	9.6%	8.2%	16.6%	6.1%	100%
LFR%	0.2		2.2	1.1		4.9	1.2	1.2	1.8	0.6	13.1

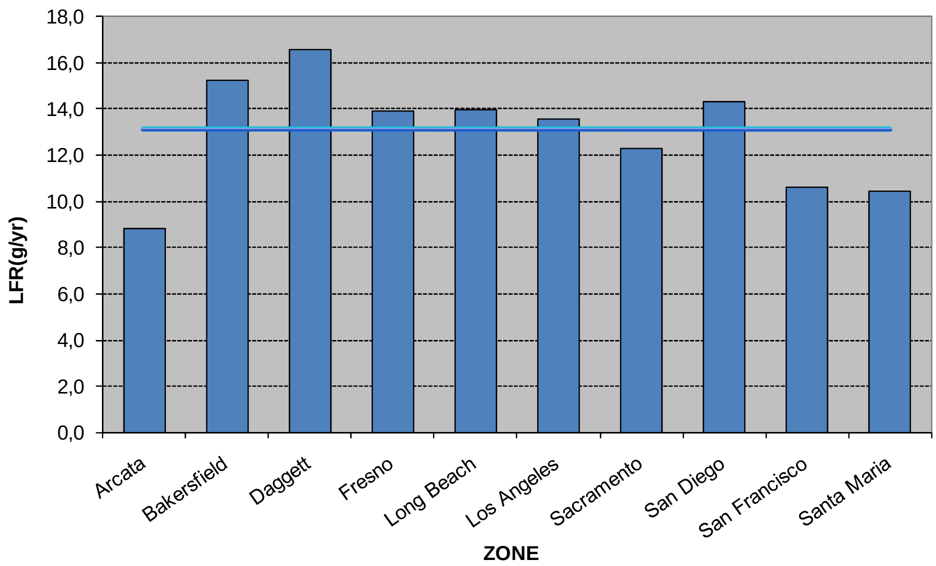


Figure 1.8: LFR variations depending on the average temperature of the 10 climatic zones and average value (line) for California.

The average value for system D in California is 13.1 g/yr.

1.2.5 MVAC system E

System specifications

Table 1.17: System specifications.

Brand	MVAC system E
Type	Family car
Motorization	-
Vintage	2006
MVAC system	Single evaporator
Nominal refrigerant charge	800 g

System design

Photo 1.6: Assembled MVAC system D.

Table 1.18: *List of components.*

Components	Numbers of components	Numbers of fittings
Compressor	1	
Condenser	1	
Evaporator	1	
Expansion valve	1	Thermal expansion valve
Liquid line	2	
Suction line	2	
Discharge line	1	
HP service valve	1	Located on the liquid line
LP service valve	1	Located on the suction line
HP sensor	1	Located on the liquid line

Leak flow rate calculation

Table 1.19: LFRs of MVAC system E.

T (°C)	Saturation Pressure (kPa)	LFR (g/yr)
30	770	24.2 ± 1.5
40	1017	45.3 ± 2.7
50	1318	82.3 ± 4.9

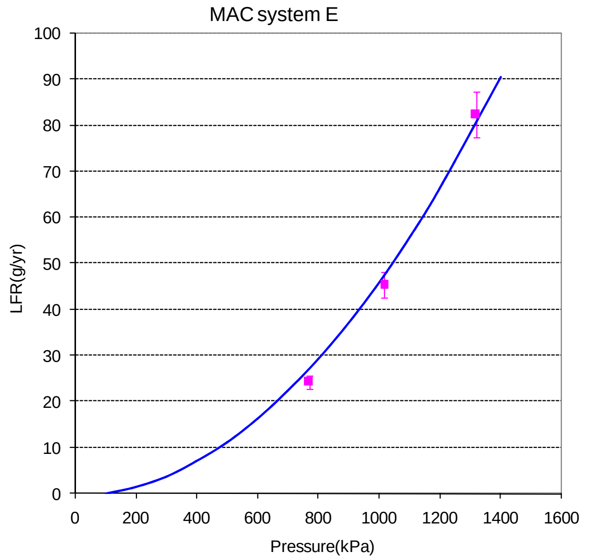


Figure 1.9*:* LFRs and regression curve of MVAC system E.

Table 1.20: Determination of the annual LFR of MVAC system B taking into account CA population.

	Arcata	Bakersfield	Daggett	Fresno	Long Beach	Los Angeles	Sacramento	San Diego	San Francisco	Santa Maria	Total
Annual mean T(°C)	10.4	18.5	19.8	17.1	17.2	16.7	15.2	17.6	13.1	12.9	
Saturation Pressure(kPa)	420	546	568	522	523	516	492	530	459	456	
					K= 4.636E-05						
LFR(g/yr)	7.7	13.3	14.5	12.2	12.2	11.9	10.7	12.5	9.3	9.2	
Population	790525		4669274	2962948		12901515	3443421	2933929	5966569	2173073	35841254
% Population	2.2%		13.0%	8.3%		36.0%	9.6%	8.2%	16.6%	6.1%	100%
LFR%	0.2		1.9	1.0		4.3	1.0	1.0	1.5	0.6	**11.5**

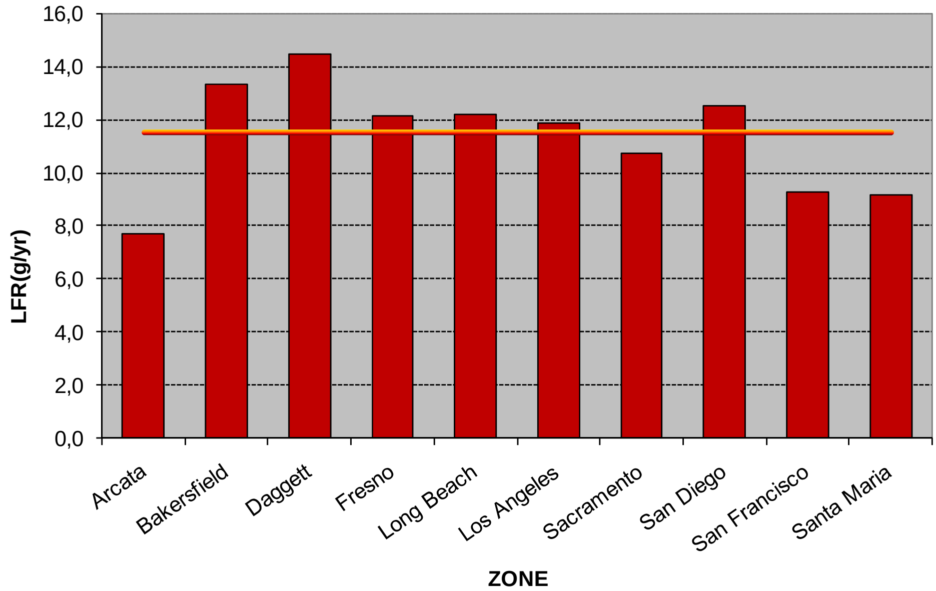


Figure 1.10: LFR variations depending on the average temperature of the 10 climatic zones and average value (line) for California.

The average value for system E in California is 11.5 g/yr.

1.3 Conclusions

The annual leak flow rate of all brand new vehicles of a given year are related to the annual average temperature of a given climatic zone and the number of brand new cars in this zone. So it is possible to derive an average annual LFR for California for brand new cars, based on bithe the population of cars and the climatic zone. The assumption has been made that the population of car is directly related to the population itself. From Figures 1.11 and 1.12, it appears that the annual leak flow rate from brand new cars running in California depends more on the population than on temperature differences. With 36% of the total population, the annual LFR for Los Angeles represents 36% of the global LFR in California even though its average annual temperature of 16°C.

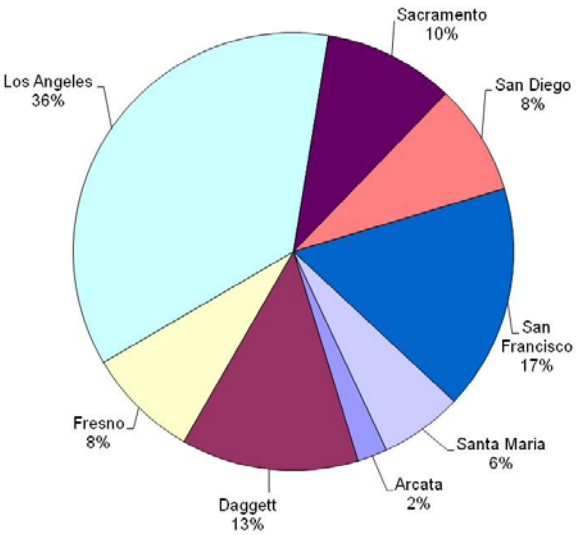


Figure 1.11: Population distribution.

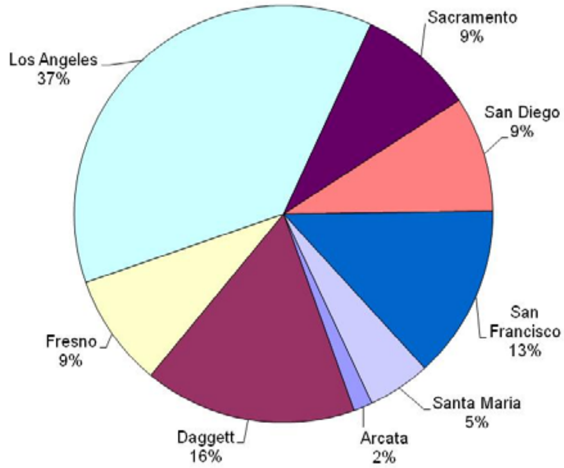


Figure 1.12: Annual LFR distribution as a function of population and zones temperatures.

System	K	LFR@Temp
A	2.536E-05	6.3
B	3.382E-05	8.4
C	2.093E-05	5.2
D	5.295E-05	13.1
E	4.636E-05	11.5

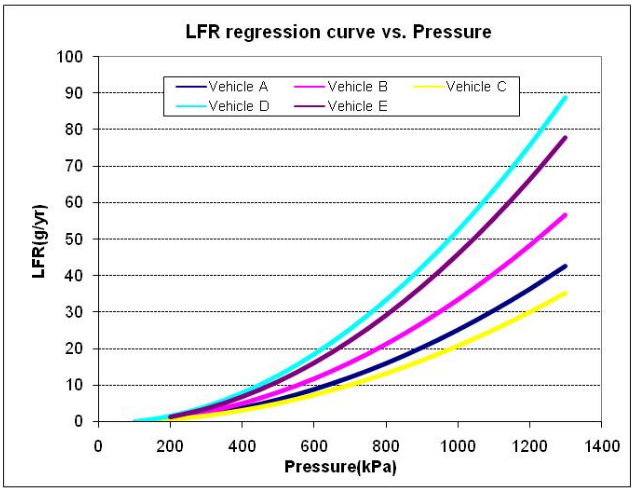


Figure 1.13: Vehicle annual LFR as a function of the pressure.

Another major conclusion can be drawn: the results of LFRs of MVAC systems of the five most sold cars in California confirm that the automotive industry is a global one. Also the LFRs of MVAC systems, as measured in Europe or Japan on fleet of vehicles and in laboratories, lead to the same order of magnitude: the average annual LFR of new systems is in the range of

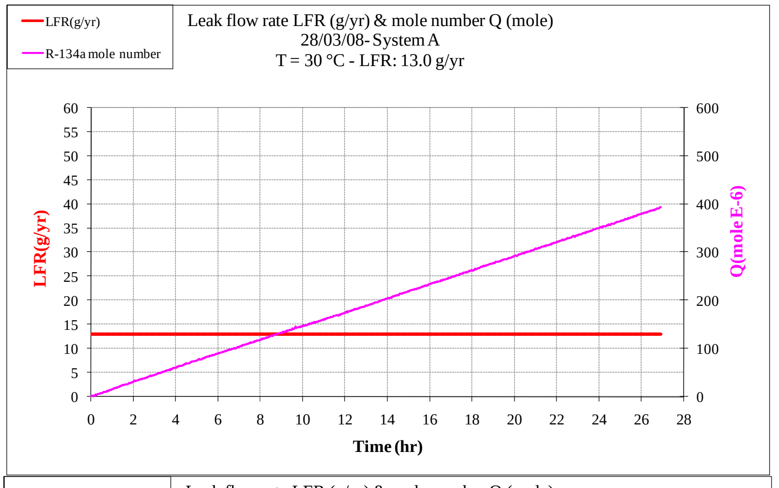
10 g/yr ±4 and possibly higher for some double evaporator systems. It can be derived from that conclusion that, except for ill-assembled systems or weak components, MVAC systems should not be refilled before at least 6 to 7 years from the initial sale date of the vehicle. This number takes indirectly into account leak tightness degradation, because if the original level of leak tightness is kept all along the lifetime of the vehicle, it should be unnecessary to recharge any vehicle before at least 20 years, which is obviously not the case due to the large quantity of refrigerant sold for the servicing of MVAC systems. CARB has carried out several studies in order to better understand emission patterns of vehicles. Vincent et al [VIN04] have shown that the most serviced MVAC systems are occurring at about 8 to 9 years of the lifetime of the vehicle. They have derived, from a study made on more than 12,500 vehicles that the average emission rate over the lifetime of vehicles is about 80 g/yr, taking into account all emissions.

Nevertheless, the initial level of leak tightness is certainly kept during the guarantee period, which is from 3 to 5 years depending on brand names. Complementary research work is needed in order to understand leaks. One of the leak prone components, the compressor shaft seal, has to be studied in laboratory conditions by acceleration of the aging process and taking into account that the emission level of the shaft seal is more significant when the compressor is stopped compared to when the compressor is running, because running time is only 2 to 4% of the annual time.

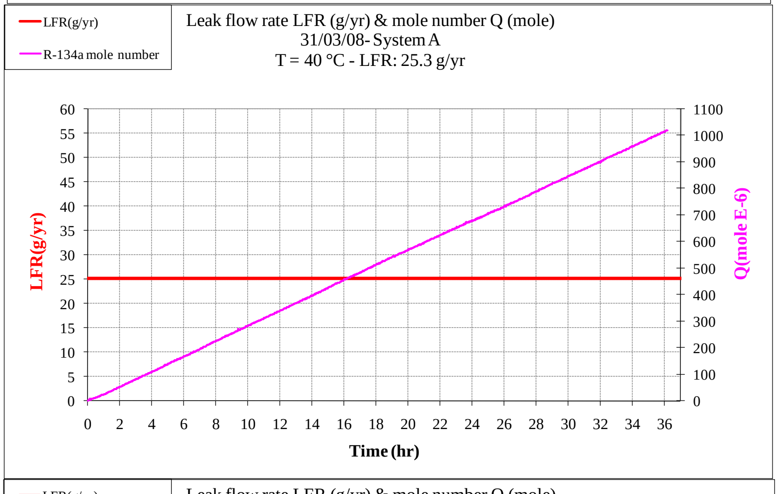
Appendix 1a: Leak flow rate and mole number graph MVAC system A

Note: in those appendices, the horizontal line indicates the leak mass flow rate expressed in g/yr, and the value has to be read on the left ordinate side, while the variation of the concentration is expressed in moles and is read on the right ordinate side.

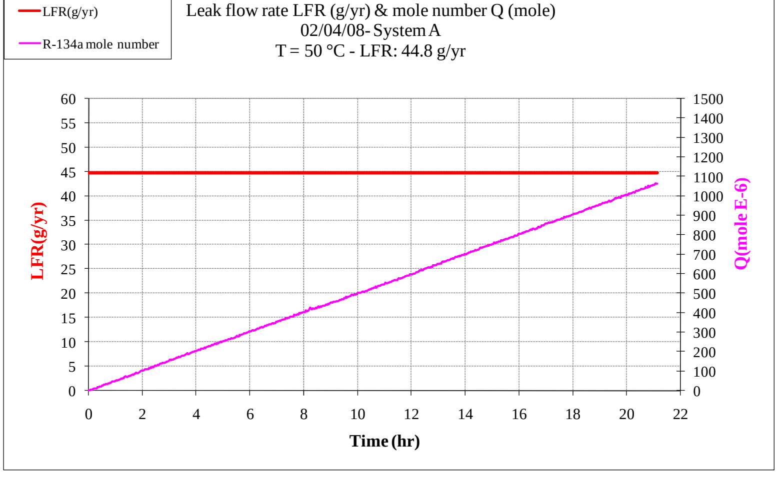
T = 30°C



T = 40°C

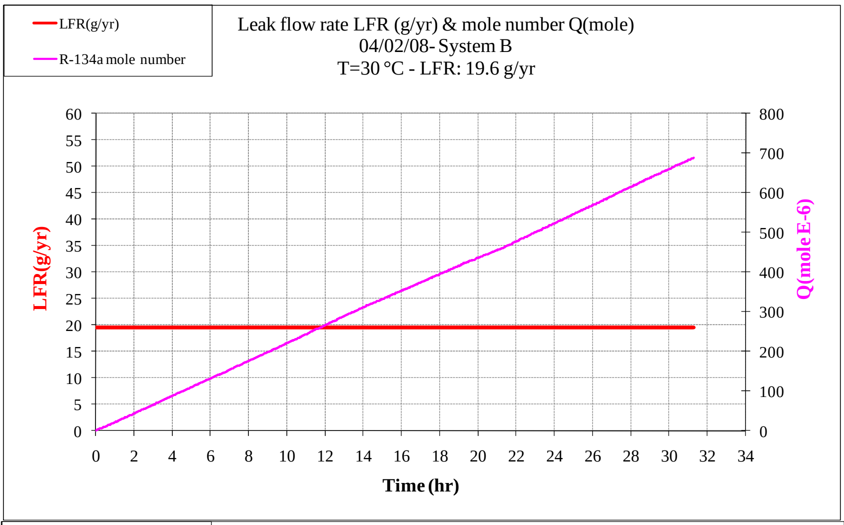


T = 50°C

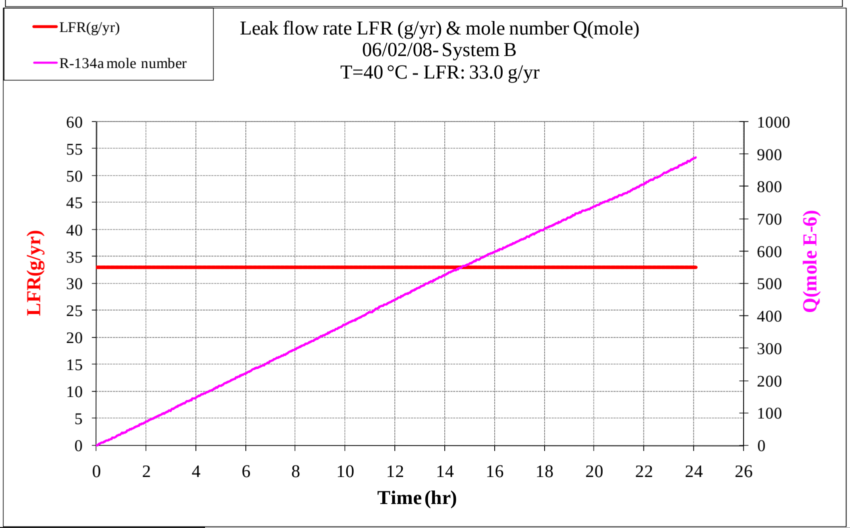


Appendix 1b: Leak flow rate and mole number graph MVAC system B

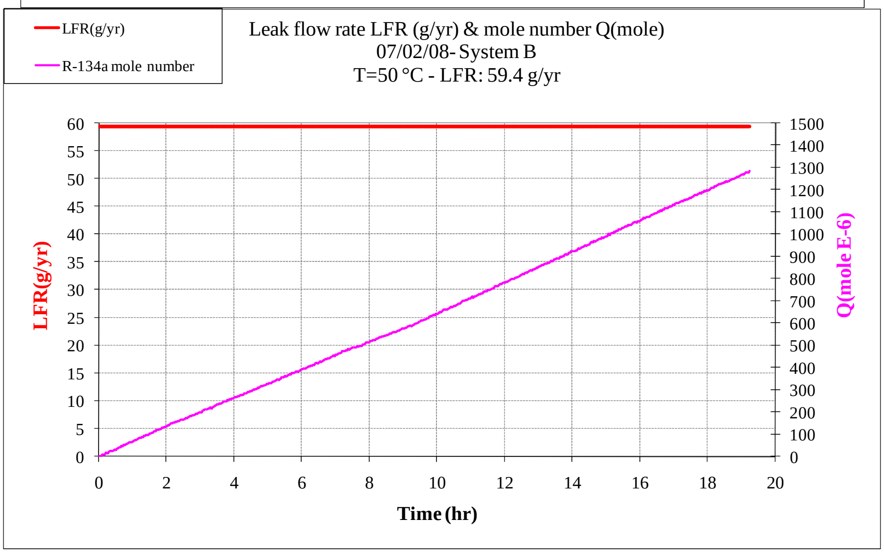
T = 30°C



T = 40°C

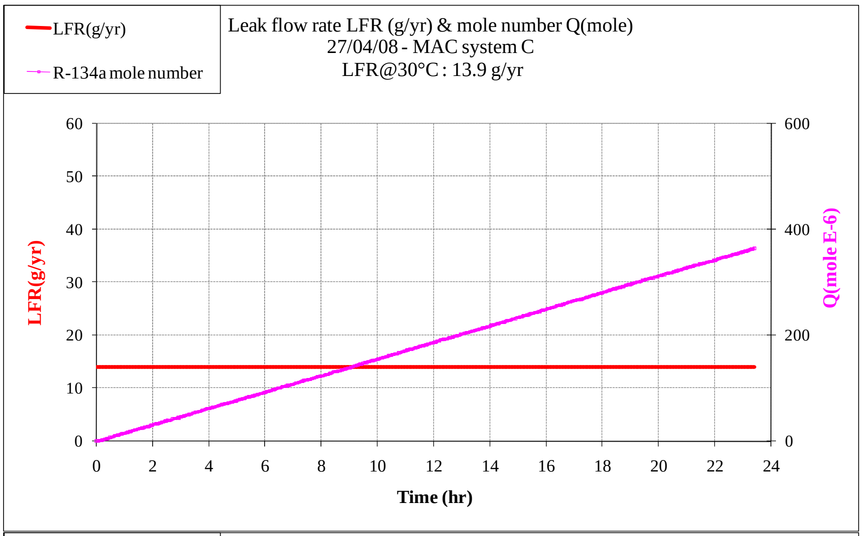


T = 50°C

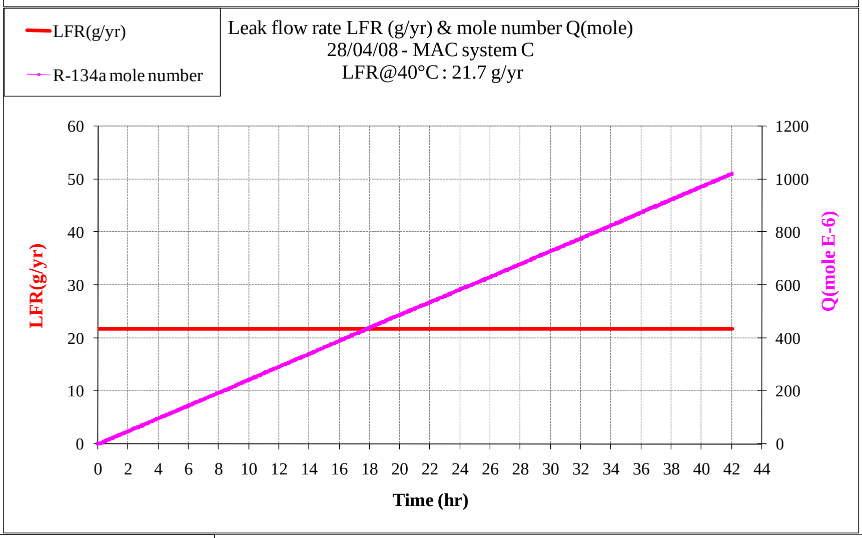


Appendix 1c: Leak flow rate and mole number graph MVAC system C

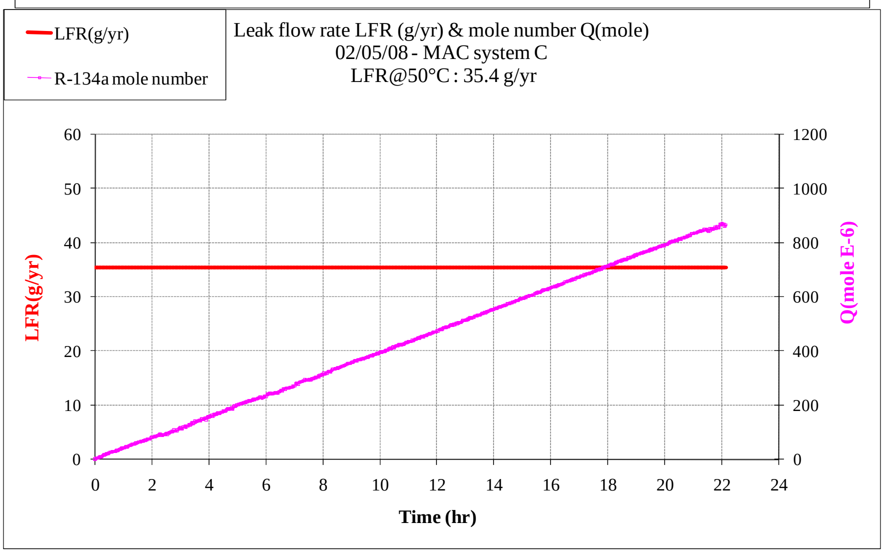
T = 30°C



T = 40°C

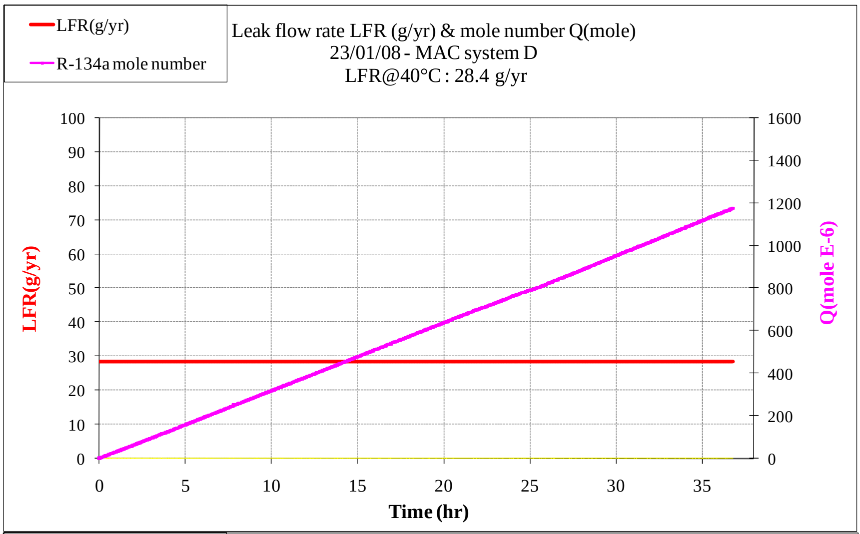


T = 50°C

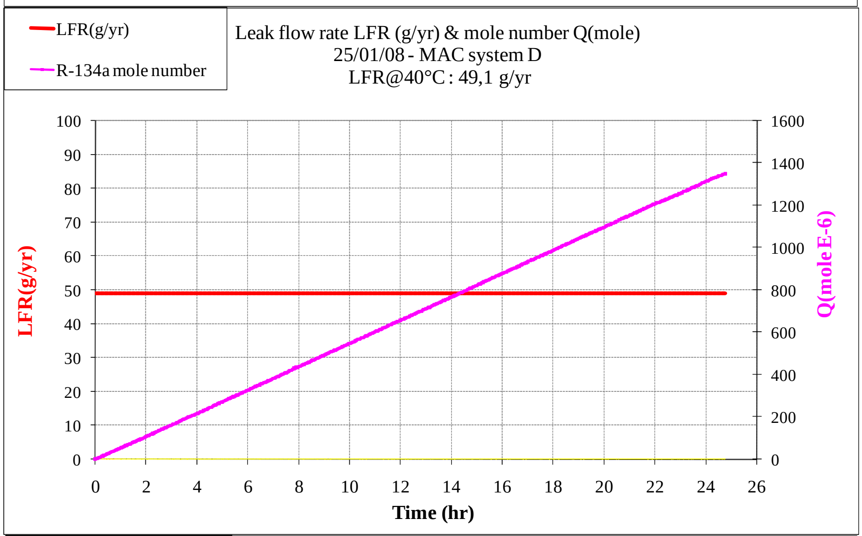


Appendix 1d: Leak flow rate and mole number graph MVAC system D

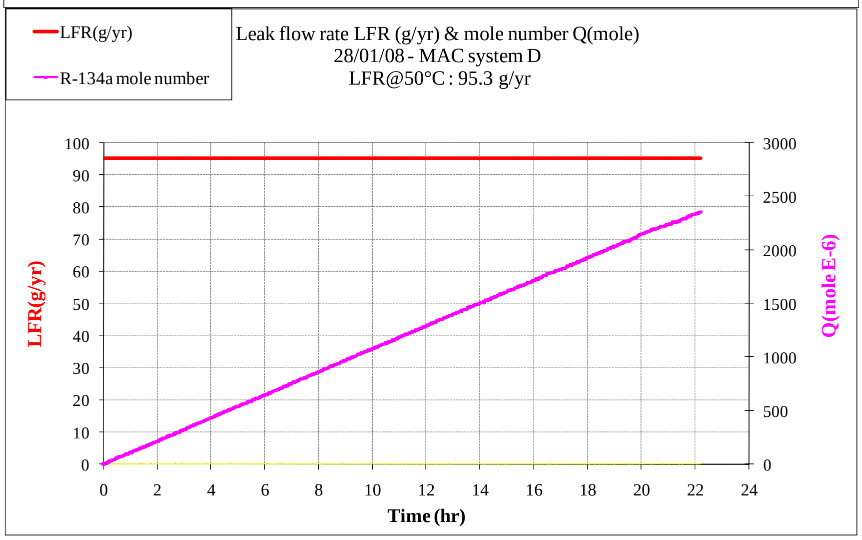
T = 30°C



T = 40°C

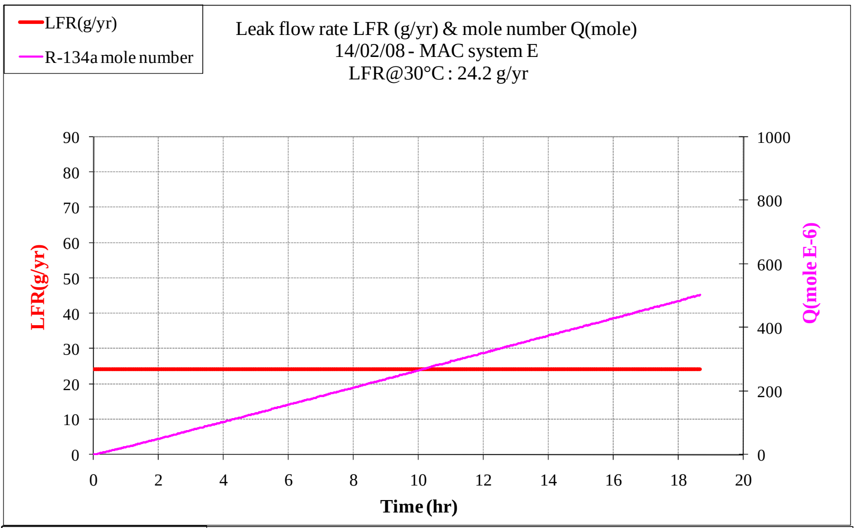


T = 50°C

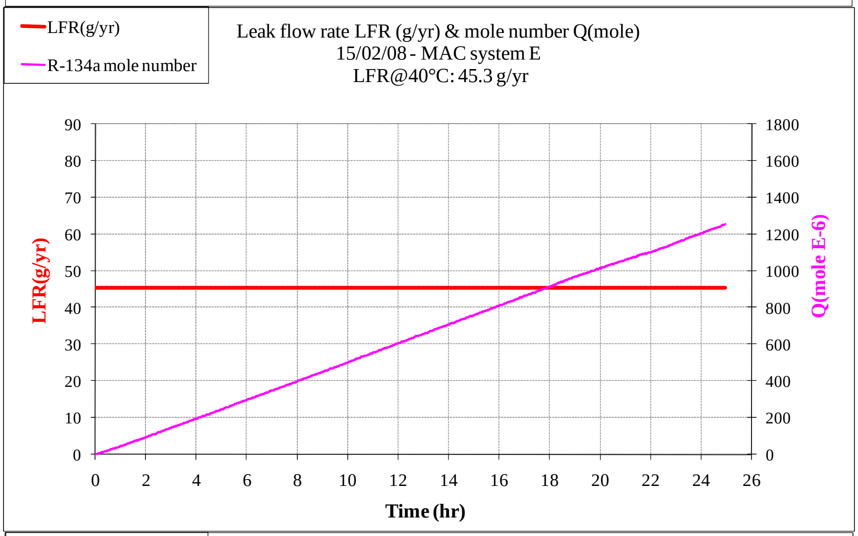


Appendix 1e: Leak flow rate and mole number graph MVAC system E

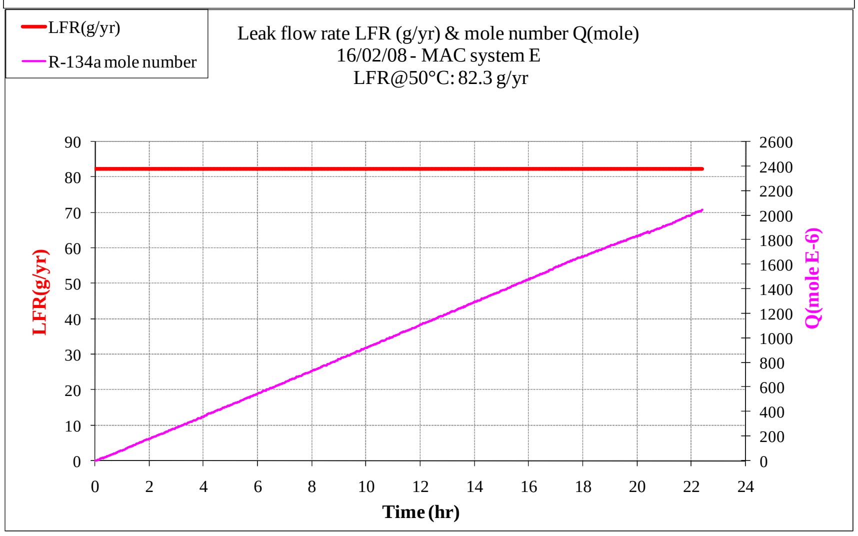
T = 30°C



T = 40°C



T = 50°C



2. Analysis of current recharge by non professionals in California

2.1 Introduction

In order to evaluate the potential impact of HFC-134a emissions from non-professional servicing of motor vehicle air conditioning (MVAC) systems, field tests have been carried out in order to measure refrigerant emissions during 45 real refilling operations of MVAC systems.

The research project aims at identifying emission rates due to non-professional servicing compared to professional servicing based on servicing operating modes observed in the state of California.

By definition, a leaky MVAC system will release its entire refrigerant content to the atmosphere if the refrigerant leak is significant. The MVAC system leak flow rates imply one or several recharge(s) of the MVAC system along the lifetime of the vehicle. During a charging process, refrigerant emissions could be classified into two categories:

- Direct emissions due to leak from disposable containers (cans or cylinders), hoses, and fittings;
- Heel emissions due to the refrigerant remaining in disposable containers after charging.

Section 2.2 describes the disposable small cans available on the Californian market, its contents, prices and types. Appendix A present photos and characteristics of those disposable cans. The leaks before and after use of some can samples are measured in the laboratory and presented hereafter.

Analysis of current recharge by non-professionals, Do-It-Yourselfers (DIYers), in California is presented in Section 2.3. The know-how and the expert skills have to be taken into account when drawing conclusions. Two sampling groups of non-professionals are considered and classified, based on their qualification. Analyses will be made for each sampling group as well as for the total number of 50 non-professionals DIYers who have recharged different MVAC systems.

2.2 Small cans: description and leak test results

Small can description

Two categories of small cans (SC) are available on the Californian market:

- Cans to be screwed and perforated (Photo 2.1)
- Cans equipped with a valve and an optional pressure gauge (Photo 2.2)

Cans to be screwed and perforated are proposed in different capacities: 12, 13, 14, 18, and 19 oz. Cans equipped with valve are available in 14 oz. and 19 oz. capacities.

Photo 2.1: Can to be screwed and perforated.

Photo 2.2: Can equipped with a valve and pressure gauge.

Photo 2.3: Re-usable charging kit for small cans to be perforated and screwed.

Cans to be screwed and perforated (S&P) are connected to a charging kit. Photo 2.3 presents an example of a charging kit. This charging kit is usually composed of:

- Can tap: perforating valve, with a screw fitting
- Flexible hose
- Service valve adaptor: Low Pressure fitting
- A pressure gauge (optional)

Table 2.1 lists a large variety of small cans available on the Californian market, their type, content, market price, and on-line net price. A list of small cans and their characteristics is presented in Appendix A.

Table 2.1: Small cans details.

SC brand name	**Model**	**Type**	**Content**	**Price Kragen**	**Price Kragen 2**	**Price Net www.partsamerica.com/**
Quest	Normal	S&P	12 oz.		7.99 $	
Quest	UV	S&P	12 oz.		11.99 $	
Quest	Stop Leak	S&P	12 oz.		11.99 $	
Quest	Sub Zero Polar Bear	S&P + reusable kit	19 oz.	28.99 $	25.99 $	24.99 $
Johnsen		S&P	12 oz.	7.99 $	8.99 $	8.99 $
Johnsen	UV Dye	S&P	12 oz.		14.99 $	
Interdynamics	EZ Chill	Valve equipped	14 oz.	21.99 $	17.99 $	
Interdynamics	Arctic Freeze	S&P	13 oz.		13.99 $	12.99 $
Interdynamics	Arctic Freeze	Valve equipped + Pgauge	12 oz.		39.99 $	
Interdynamics	Arctic Freeze	Valve equipped	19 oz.			32.99 $
Interdynamics	Arctic Freeze with Reusable Trigger	Valve equipped	14 oz.			26.99 $
Interdynamics	EZ Chill+hose	Valve equipped			28.99 $	
Interdynamics	EZ Chill Measure/Recharge Kit	Valve equipped + Pgauge	19 oz.			24.99 $
Interdynamics	Artic Freeze	S&P	18 oz.			27.99 $

To conclude, it is obvious that S&P cans are cheaper than those with valve or valve + pressure gauge equipped. The S&P price varies according to the refrigerant content and the brand name. For this reason, people prefer to buy the charging kit for once and then reuse it with S&P cans. S&Ps are dominant (nearly 90% of the market, as assessed by several dealers) for two reasons: the more knowledgeable DIYers buy S&Ps due to the easiness of use; less knowledgeable, but price-oriented DIYers are also choosing S&Ps.

2.3 Analysis of recharge by do-it-yourselfers (DIYers)

The aim of this section is to determine the refrigerant emissions when a MVAC is charged by a DIYer. In fact, when charging its own car, a DIYer releases directly and indirectly refrigerant to the atmosphere. Direct emissions are those emitted during the charging process (leaks from the hose, can tap, and service valve adaptor). Indirect emissions known as “heel emissions” are refrigerant remaining in the can after the DIYer disconnects the service valve adaptor. If the kit is leaking, later or sooner the refrigerant remaining in the can will be released. An operating procedure has to be established in order to assess the different refrigerant emissions and the effective mass charged in the MVAC.

2.3.1 Operating procedure for emission assessment

The operating procedure used to evaluate refrigerant emissions is carried out according to the following method described here below.

- The CEP team realizes an initial refrigerant recovery. The refrigerant charge of the MVAC system is recovered (and weighed) in order to evaluate the efficiency of the charge operation made by the SCU (small can user) with small can(s).
- The CEP team performs an initial and partial charge of the AC loop (typically 1/3 of the original charge), in order to perform the charging process under realistic conditions: the pressure is the saturating pressure of R-134a.
  Note: If the system is evacuated and maintained under a relative vacuum, the charge with small cans is not representative of the usual use.
- Before the beginning of the SCU operation, the different types of small cans are presented. The SCU is free to choose the one he wants, or the type he usually uses for charging the AC system.
- The SCU proceeds by charging his AC system. He is free to use the number of small cans he wants. The CEP personnel takes mental notes of the operation steps. After the operation, the description is written on a dedicated field report.
- The CEP evaluates the refrigerant emissions during the charging process as well as the can heels. Can heels are measured by weighing the can before charging and after charging, and before the de-connection from the service valve. When the can cannot be weighed because the SCU dismounts it right away, the emissions are included in the operation.
- The SCU is interviewed on his usual practice with small cans (periodicity of use, etc…) and some advices are given.
- The CEP team recovers the refrigerant from the MVAC system after the charging process and the effective refrigerant mass charged in the system is known by difference.

2.3.2 Descriptions of the small can user sample

The considered sample is of 50 DIYers. This number includes 5 persons who have been interviewed, but who have not performed the charge. They have answered the questions describing what they usually do for charging. The other 45 persons performed the charging procedure, either on their own vehicles or on the CEP cars. The 50-person sample is subdivided into two sampling groups. The first one takes into account the 30 cases presented in the first intermediate report (October 2007). The second sampling group gathers the remaining 20 cases done after the first report was presented. The second sampling group comprises persons who are relatively familiar with small cans.

Conclusions are consequently sketched for the two sampling groups as well as for the overall sample. Conclusions are intentionally subdivided into three groups in order to take into account the qualification and the know-how consequence on the refrigerant release.

Sample 1 includes persons who have been interviewed, observed doing the charging process (5 persons), and those who performed the charging procedure, either on their own vehicles or on the CEP rental cars (25 persons). The 25 cases include:
- 16 persons (all not SC experts), who have charged the MVAC system of their own vehicles
- 6 others persons, who have made the refrigerant charge of the CEP rental car (Chevrolet), and
- 3 others who have made the refrigerant charge on the Cadillac used by Simon and Martin.

Sample 2 includes 20 cases where the charging process was made on the CEP car (Mitsubishi). The CEP team was asking for help from persons near auto parts stores due to malfunctioning of the Mitsubishi MVAC system. 17 persons have made the operation, 3 have indicated to the CEP person the different steps to be done. The CEP team performs exactly what the person tells him to do.

The first sample of small can users is mainly composed of males. Two saleswomen working at the Kragen auto parts store helped the CEP team to fill their car while simulating a defective AC. 23 persons are older than 30, and 5 are familiar with car self-servicing, but they are not experts in air conditioning (cf. Figure 2.1). 67 % of the 30 persons declared that they had already used small cans on their car air conditioner. The others have never used small cans before, but they were interested either for curiosity or for saving money (avoiding a garage refill).

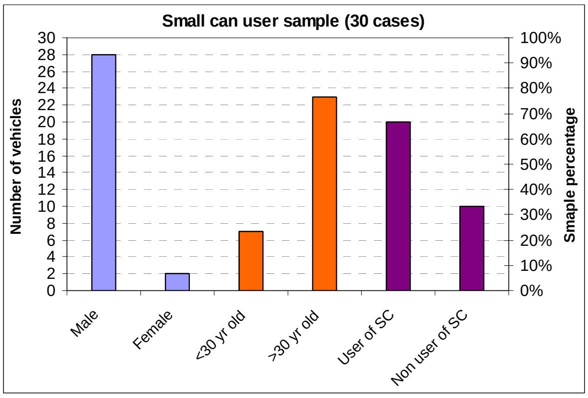


Figure 2.1: Small can users - Sample 1 description.

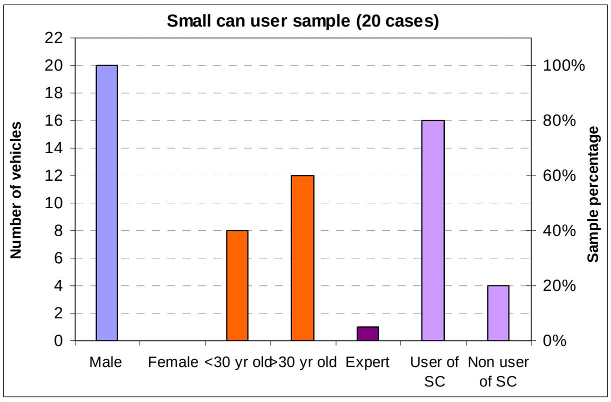


Figure 2.2: Small can users - Sample 2 description.

Note: percentages are expressed for each couple of data (male/female, < 30 yr old/> 30 yr old, and so on).

For the second sample, all persons are men, among whom 12 persons are older than 30. 80% of the 20 persons acknowledged the use of SC. They made before the charging procedure on their own car or on a family member car or, at least, they watched someone making it before. The second sample comprises a large proportion of users familiar with SCs compared to the first sample (cf. Figure 2.2).

Now, considering the whole sample of 50 persons, more than 72% of the samples have used a small can before (cf. Figure 2.3). 40% are familiar with car self-servicing, meaning that they know how to proceed for recharging the MVAC (nevertheless they can make wrong operations sometimes).

SC: Small Cans
SCU: Small Can Users

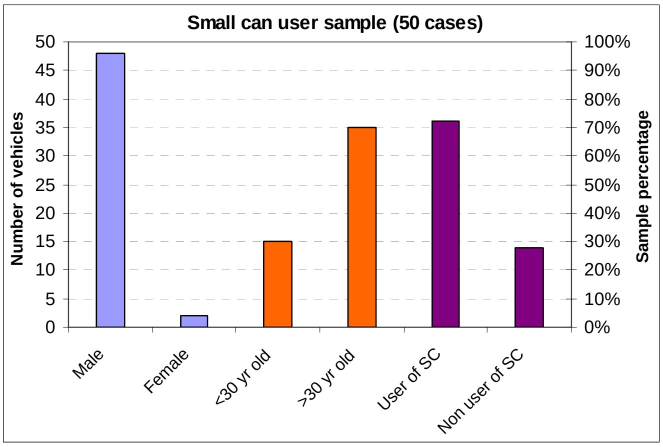


Figure 2.3: Small can users - Sample description.

2.3.3 Vehicle analysis

Figure 2.4 illustrates the vintage of the 30 cases studied in the first sample. Five vehicles were originally filled with R-12 (vintage 1990 and 1991), but the retrofit to R-134a has been done previously, and the AC loop was equipped with R-134a fitting when the charge with small can has been done. The 5 cases on retrofitted R-12 vehicles include three refrigerant charging of the Cadillac used by Simon and Martin.

The CEP rental car (Chevrolet) has been used 8 times (2 times for interviews and observing people helping the CEP team, and 6 times for a charging procedure). The Cadillac is used three times for charging process.

The 20 cases of Sample 2 were studied on the CEP car, a Mitsubishi Montero 1999 vintage.

The over whole number of recharging procedures made are 45 distributed as follows:

- 16 different vehicles own by the DIYers,
- 6 times on the CEP rental car (Chevrolet),
- 3 times on the Cadillac (M&S) and
- 20 times on the CEP Mitsubishi car.

Car vintage of the 16 vehicles owned by the DIYers

As shown on Figure 2.4, most cars were less than 10 years old. When looking at Figures 2.4 and 2.5, one can wander whether or not the older car had the lower refrigerant charge. In fact, no, the distribution of low refrigerant charges remaining in the MVAC system is not related to the car vintage.

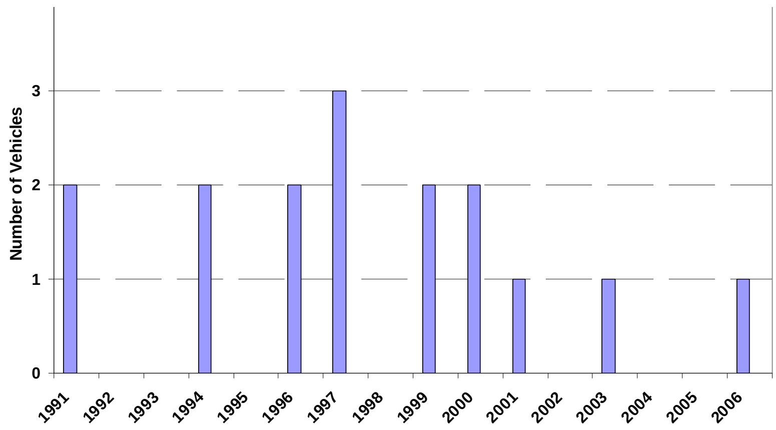


Figure 2.4: Car vintage for the 16 vehicles owned by the DIYers.

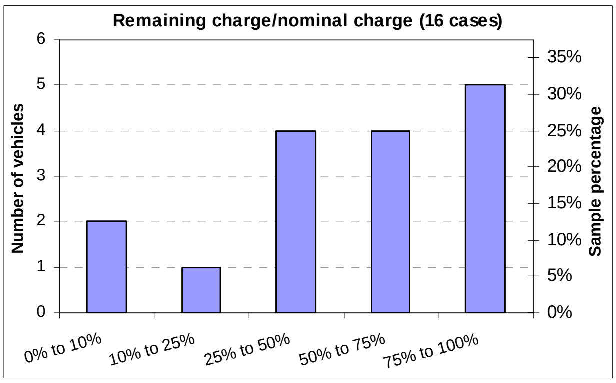


Figure 2.5: Remaining charge / nominal charge before the SC charging.

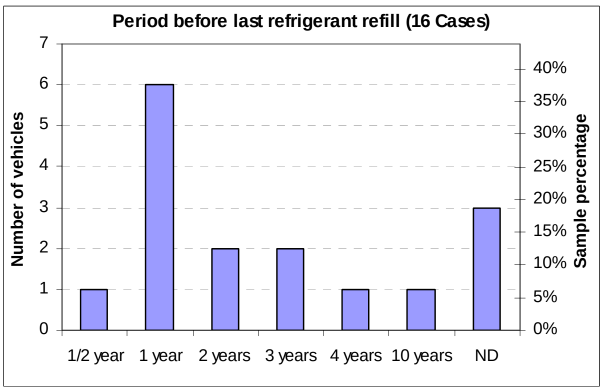


Figure 2.6: Periodicity of small can use.
ND: Not Defined

Figure 2.5 shows the remaining charge of each vehicle, measured before the charging process with small can. It indicates the number of vehicles (left scale) and the percentage on the sample (right scale). They are classified in categories depending on their initial refrigerant content (x axis).

2 vehicles were nearly empty of refrigerant before the operation. One third of the sample has an remaining refrigerant charge between 75% and 100% of the nominal charge. 25% of the sample has their AC working with a charge between 50 to 75%. 45 % have their system either working very bad (25%) or not working at all (20%). Nearly 45% of people check their AC annually (cf. Figure 2.6). After the recovery, all AC systems have been evacuated and recharged with a partial charge (1/3 of the corresponding nominal charge).

2.3.4 Charging procedure evaluation

Choice of small can

DIYers have to choose the small can type they want. Most of them chose the S&C type. 77% and 80 % chose the S&P type respectively for Samples 1 and 2 (see Figures 2.7 and 2.8). The 12-oz. capacity can, the smaller one, is preferred to the others, which represent nearly 64% of the overall sample (cf. Figure 2.9).

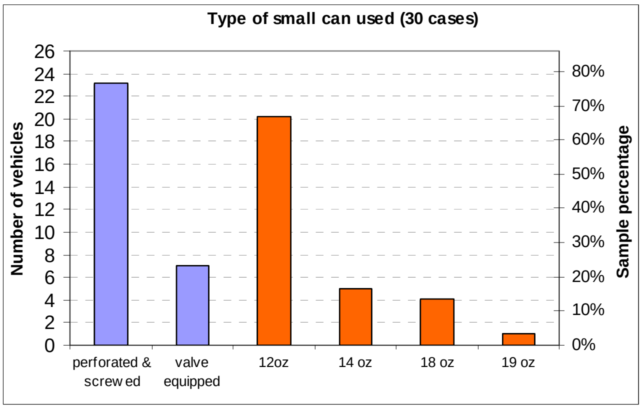


Figure 2.7: Type and capacity of small can chosen by the users (Sample 1).

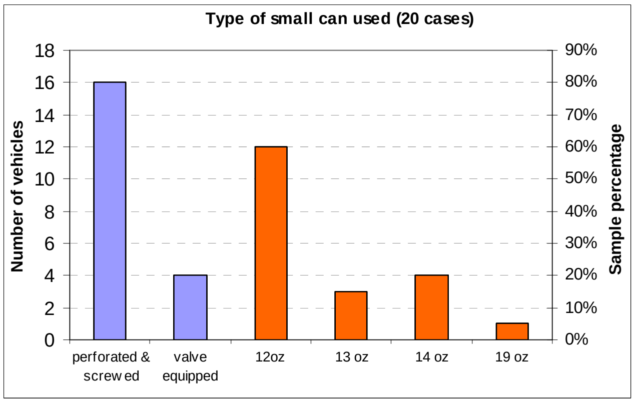


Figure 2.8: Type and capacity of small can chosen by the users (Sample 2).

Note: percentages are applicable on one side for the S&P and V types, and on the other for the refrigerant quantity, whatever the type.

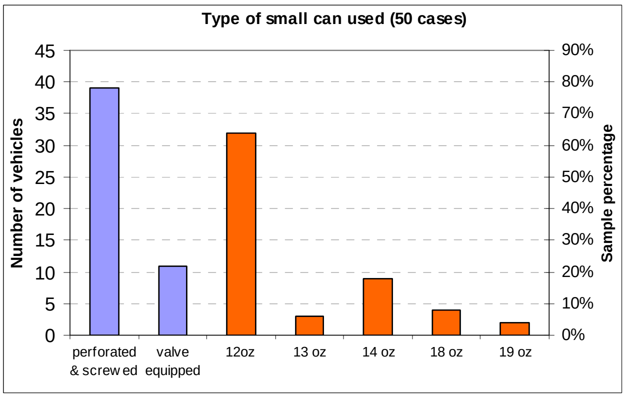


Figure 2.9: Type and capacity of small can chosen by the users (overall sample).

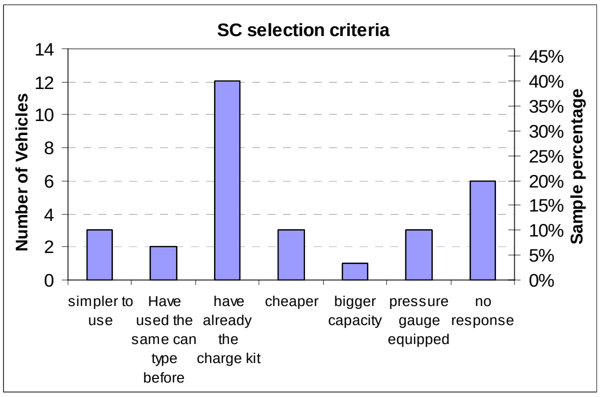


Figure 2.10: Criteria for small can type choice.

Figure 2.10 indicates selection criteria announced by the users. The most frequent one is the charging kit that can be used each time, after buying a small can to be screwed. Referred to Table 1.1, the price of the valve-equipped can is 2 to 3 times higher than that of the S&P can. In addition, if the SCU wanted to use more than one can, he would prefer to buy the S&P with the reusable charging kit.

Based on the number of persons who had already performed the procedure on their own vehicles, 63% of small can users have decided to recharge their AC because of a lack of cooling performance (cf. Figure 2.11). This fact is consistent with the analysis of the refrigerant content (cf. Figure 2.5) before servicing: two third of the sample have a remaining refrigerant content lower than 75% of the nominal charge. Nearly half of the fleet was below 50% refrigerant nominal charge.

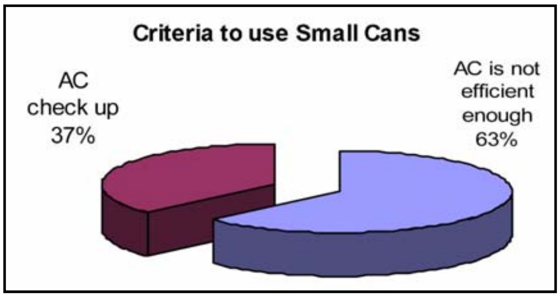


Figure 2.11: The reasons to use a small can.

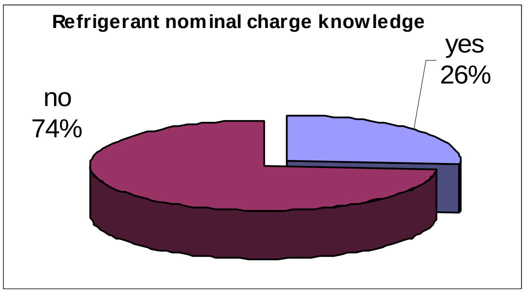


Figure 2.12: Knowledge of the AC nominal charge.

Only 26% of the small can users know the mass of refrigerant to be filled in their system (see Figure 2.12). What is amazing, in the selection criteria announced by the DIYers, is that none of them relates the can capacity to the vehicle original charge. All criteria that DIYers take into account are mentioned in Figure 2.10.

In fact, the can capacity should be an important criterion for the DIYer when choosing a SC, because the can capacity is directly linked to the system nominal charge (announced by the manufacturer) and to the remaining AC system charge. A system whose nominal charge is 900 grams needs two or more 12-oz. cans whereas it is empty or half charged.

Indeed, the information and equipment available to DIYers are usually too limited and does not allow them to know how much refrigerant to add or when the system is fully charged. This lack of information can lead to ineffective use of small cans as well as inappropriate charging of the MVAC system.

Charging procedure

No instructions were given to small can users during their operation. They were observed and the facts and actions are reported on Figures 2.13 to 2.15 respectively for the first, second, and overall samples.

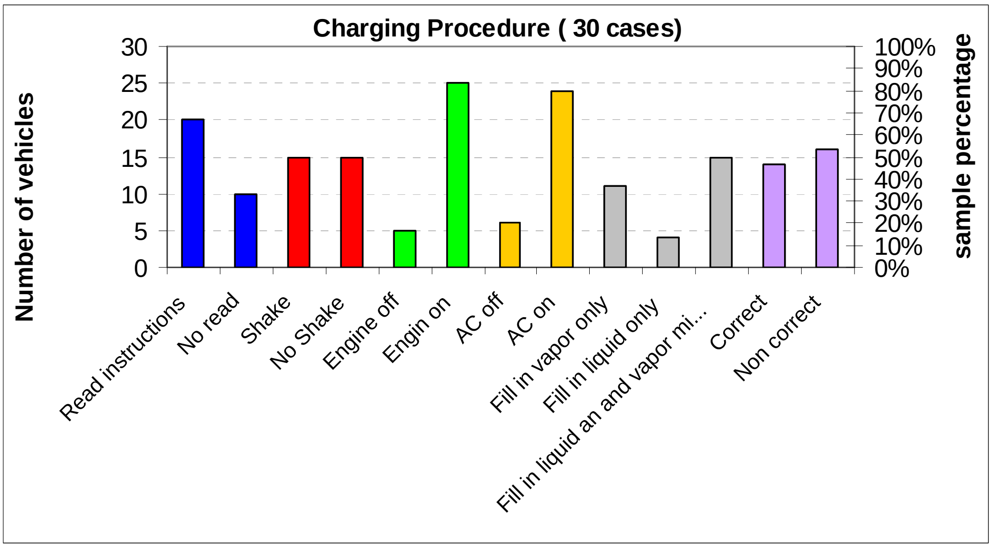


Figure 2.13: Report of facts and actions during the charging process of small can users (sample 1). Note: percentages are applicable for the couple of data (read / no read, shake / no shake, …) and for the three data vapor only / liquid only and liquid & vapor).

Sample 1 people seem to be less familiar with SCs compared to those of sample 2. This is verified on several criteria.

Reading instructions chart: nearly 67% of people read the instructions in Sample 1 compared to 35 % for sample 2. When people have used once, usually they think they know and many times do not read instructions any longer.

Engine on or off: several persons in Sample 1 did not turn the engine or the AC system ON (respectively 20 and 25%). In contrast, all persons of Sample 2 turn the engine and the AC system ON.

Shaking the can: 75% of Sample 2 shake the can during charging, while only 50% do it in Sample1.

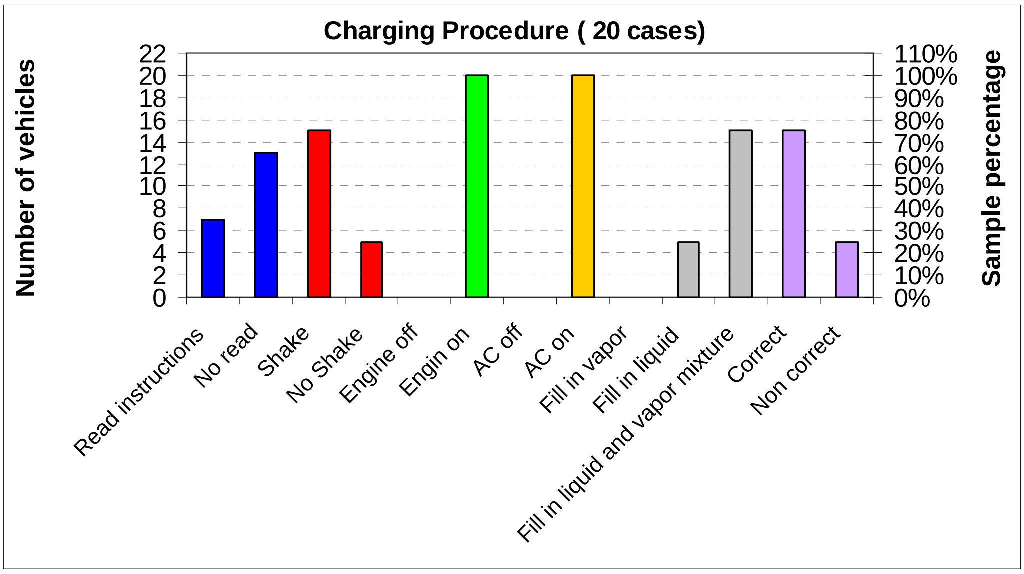


Figure 2.14: Report of facts and actions during the charging process of small can users (Sample 2).

Note: when shaking the can, nearly all SCUs were shaking it strongly. Some were shaking the can from the vertical to the horizontal position, and others were only shaking it with small amplitude (not moving it up to the horizontal position). In any cases the refrigerant charge is in two-phase flow, liquid and vapor, providing that the can is firmly shaken, which was the case of all SCUs doing so.

Nevertheless only 40% of Sample 2 made correctly the procedure compared to 27% for Sample 1. These values reflect that the familiarity with SCs is not a sufficient condition to charge correctly.

Now, considering the overall sample, more than 32% proceeded correctly by turning the engine and the AC ON, and shaking the can between horizontal and vertical positions in order to charge in both liquid and gas.

Note: when the loop is equipped with a suction line accumulator, charging in liquid phase is not dangerous for the compressor. But when there is a HP receiver associated with a thermo expansion valve (TXV), the compressor could be damaged (liquid slugging).

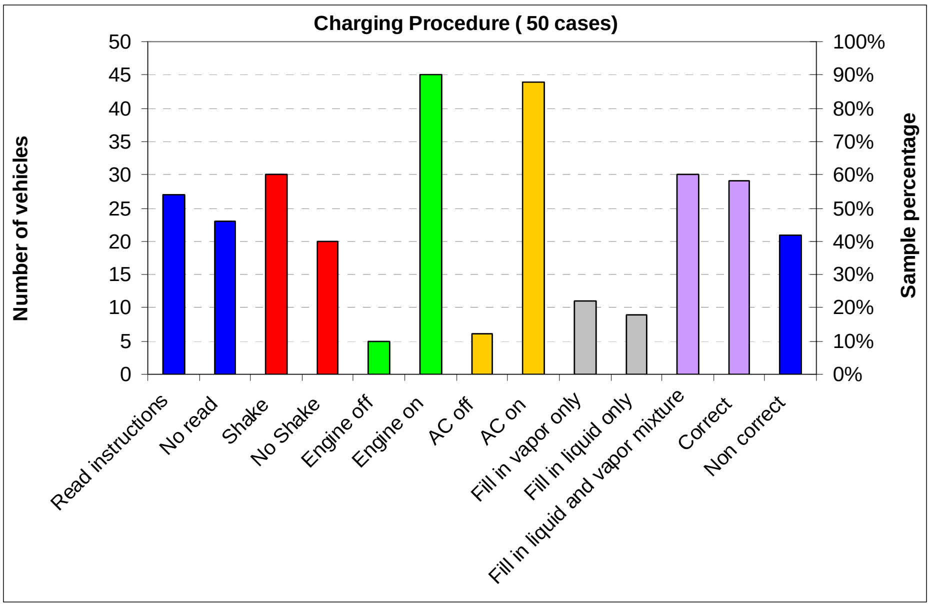


Figure 2.15**:** Report of facts and actions during the charging process of small can users (overall sample).

Criteria to stop charging the AC

Small can users were asked when they decide to stop charging the AC system. They could have answered one or two reasons (the number of answers is higher than the number of users, which is 50).

The two most frequent answers were, the air blown temperature at the AC outlet in the car and the verification by shaking that there is no more liquid in the can. 50% measured the blown air temperature in the car to make sure the cooling is effective. The measure is subjective; they do not use any temperature sensor, but still it is verification.

50% stopped the charge when the can was empty. They shake the can to state if it is empty; others feel the can temperature: when the can is still cold, it remains some refrigerant.

Note: 50% have answered they stop charging when the can is empty, but this fact does not mean that the cans are empty at the end of the different operations.

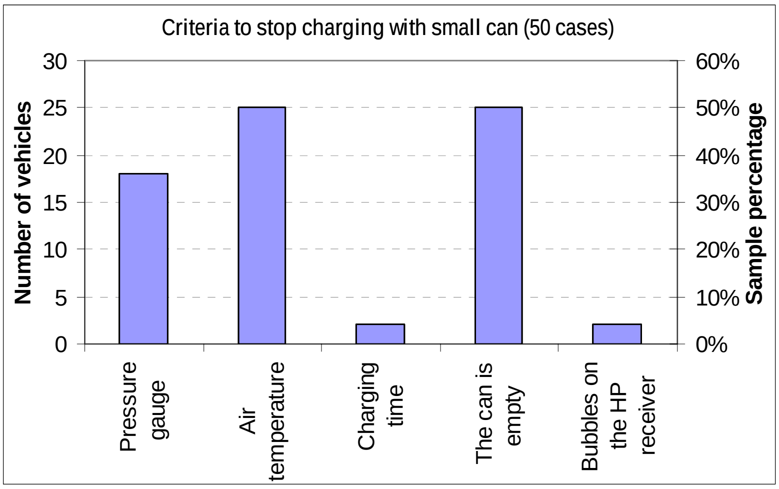


Figure 2.16: Diagnostic to stop charging.

Note: several actions can be made successively and so percentages are only an indication.

For cans equipped with pressure gauge indicator, some of the people who read the instructions written on the cans have followed the indication that the charge is correct when the "Pressure ranges between 25 psi and 40 psi". More than 35% of the answers are based on this criterion (cf. Figure 2.16). The pressure gauge indicates only the low-side system pressure showing different values and colors to indicate when the system is "undercharged", "full", or "overcharged" with refrigerant. But the system condition is dependent on more than just the amount of refrigerant in the MVAC system. The low-side pressure gauge indicates that refrigerant is circulating in the MVAC system and not the amount. A low-side gauge pressure of zero would indicate an empty system. Therefore, the kit gauge reading does not provide the information needed to determine the amount of refrigerant needed or the criteria to stop charging. On the contrary, wrong statements are delivered through the tag and the gauge.

Number of cans used to complete the refrigerant charge

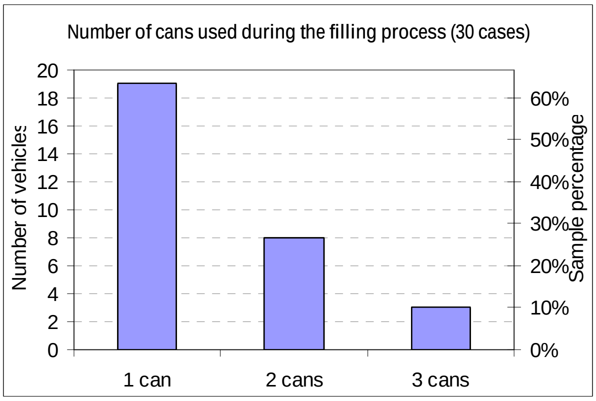


Figure 2.17: Cans used during charging (sample 1).

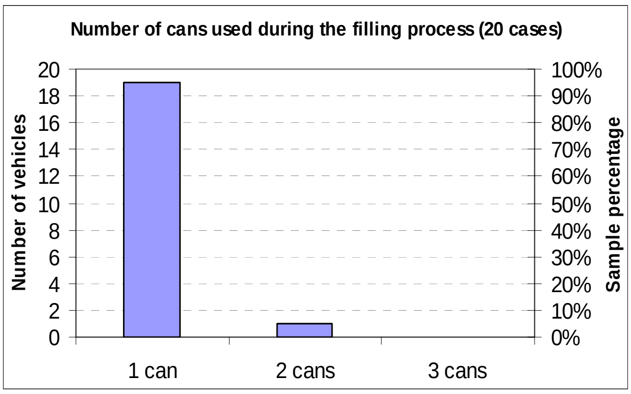


Figure 2.18: Cans used during charging (sample 2).

The number of cans used during the charging process is directly related to the know-how and the qualification of the persons. In fact, without making a complete recovery, nobody can evaluate or estimate the quantity of refrigerant to be charged. Moreover, because the exact refrigerant mass that has been charged is also unknown, the number of cans is based only on random issues. It is possible still to think that the precautionary attitude is to use only one to verify that the MVAC is generating sufficient cooling in order not to waste a lot of refrigerant in case of strong refrigerant leak.

Obviously, in Sample 1 more SCUs have used more cans than in Sample 2. 63% have used 1 can compared to 95% in Sample 2. Two of the three SCUs who used three cans did not proceed correctly. Most of small can users choose the smaller capacity cans (12 oz.) (see Figure 2.9).

As shown on Figure 2.19, nearly 76% of the operations have been done with 1 can. 18% of the operations were done with 2 cans and only 6% with 3 cans.

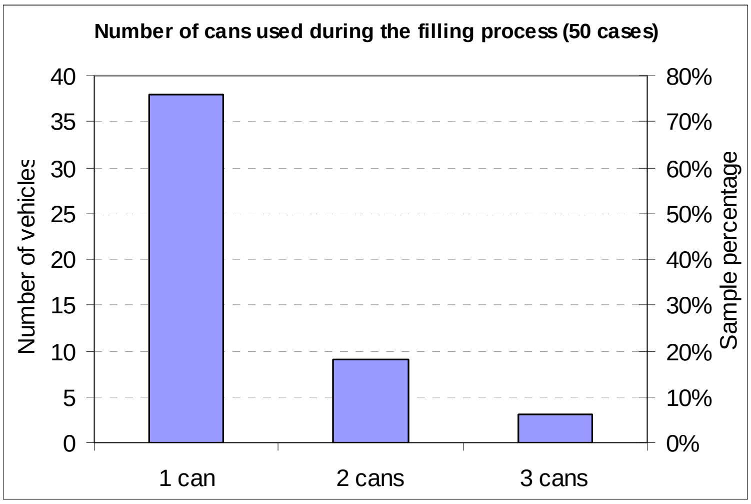


Figure 2.19: Cans used during charging (overall sample).

Refrigerant charging time

Here again, a DIYer who is familiar with SCs will recharge the system in 5 to 10 minutes, not longer. In fact, the charging time depends on both the filling mode (liquid or vapor) and on the can content. The regular time for charging a 12-oz. small can, applying the correct procedure (continuous shaking), is 5 minutes. The time is longer when the can is not shaken and 15 minutes are significantly non sufficient to evaporate the complete content of the can in the upright position. Most of cases that take longer than 20 minutes are done with more than 1 can.

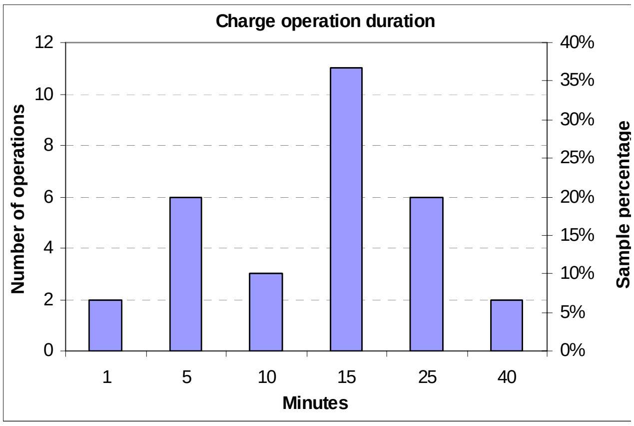


Figure 2.20: Refrigerant charging time (sample 1).

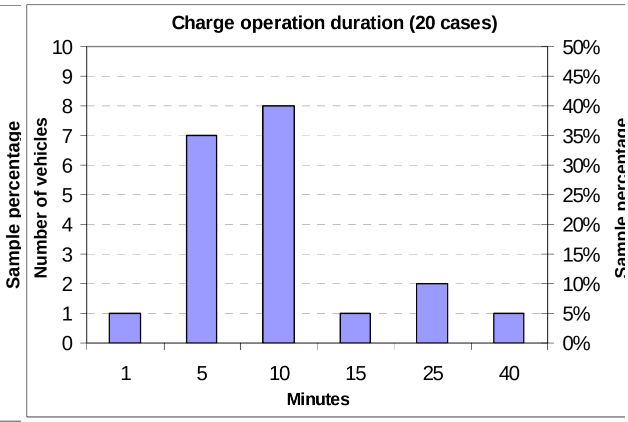


Figure 2.21: Refrigerant charging time (sample 2).

50% of Sample 1 SCUs have charged the MVAC in the upright position (vapor phase only). This will explain that the most frequent charging time is 15 minutes (see Figure 2.20). Only 30% of operations took between 5 and 10 minutes.

In contrast, 75% of Sample 2 have charged while shaking the can between upright vertical and horizontal positions. The most frequent charging times are 5 and 10 minutes, which is consistent (cf. Figure 2.21). 40% of operations took 10 minutes and 35% took 5 minutes.

Figures 2.20 and 2.21 indicate that 2, respectively 1, charging operations have been done in only 1 minute. Two reasons for those too short operations:

- The SCU reads the pressure gauge indicator and stops charging because the pressure seems to be correct. The charge with a small can is limited to the pressure equilibrium. In this case, most of the refrigerant remains in the can.
- The operator does not recognize how to proceed, so he stops the operation a short time after the beginning.

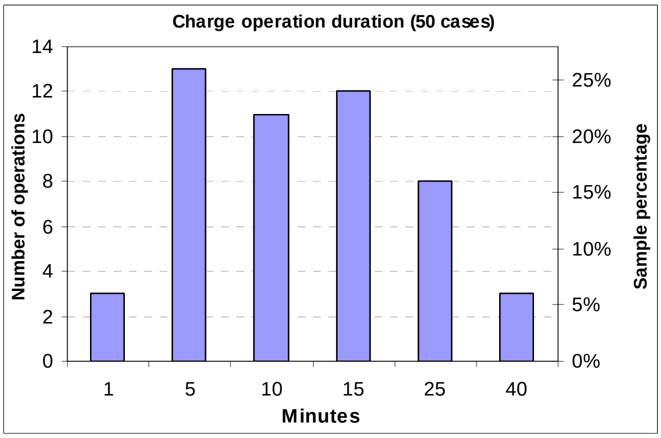


Figure 2.22: Refrigerant charging time (overall sample).

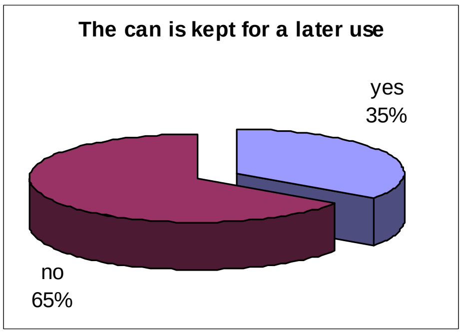


Figure 2. 23: Part of people who keep the can after use.

Considering the charging time for the overall sample, nearly 50% took from 5 to 10 minutes. 5% took less than 1 minute and 5 % took more than 40 minutes. Cases where the charging process took 25 minutes are due to two reasons: vapor charging or more than 1 can has been charged.

After the charging operation, some refrigerant could remain in the can, especially when the can capacity is large, or when the charging operation is performed in vapor phase. When the SCU is using a small can equipped with a valve, the can is reusable. But for perforated cans, refrigerant is completely released when disconnecting the can. According to the field survey, 2 thirds of SCUs declare they will not keep the can after use (see Figure 2.23).

2.3.5 Refrigerant emissions associated to the use of small cans

Refrigerant emissions during the charging process

As presented in Section 2.3, the total number of vehicles tested is 45 including the 16 vehicles owned by the SCUs, 29 operations being done on the CEP cars.

The initial refrigerant content of the MVAC system is known. The small can has been weighted before and after the charging process. The difference corresponds to the refrigerant mass released from the can: the first part is filled in the AC circuit; the second part is released during the charging process.

Once the refrigerant recovery is performed, the precise system charge using the small can is measured by difference with the known initial charge (1/3 of the original charge). The difference between the refrigerant contained in the can (initial weighing), and the refrigerant mass really filled in the MVAC circuit is the refrigerant emission during the charging process, plus the refrigerant heel remaining in the can.

Figures 2.24 to 2.29 illustrate the emissions due to servicing, the can heel as well as the overall emissions for the overall sample (45 cases). Results corresponding to Samples 1 and 2 alone are presented separately in Appendix B.

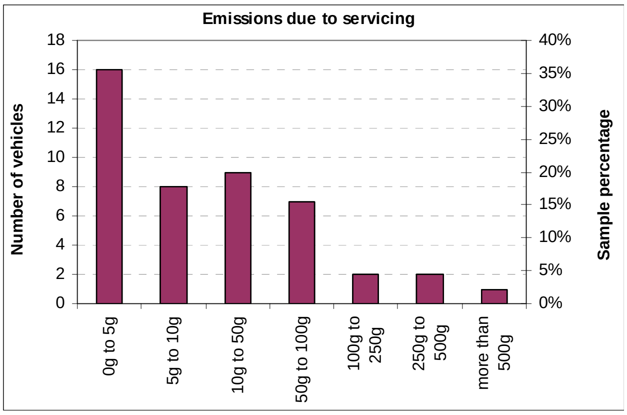


Figure 2.24: Number of vehicles as a function of emission range due to servicing (overall sample).

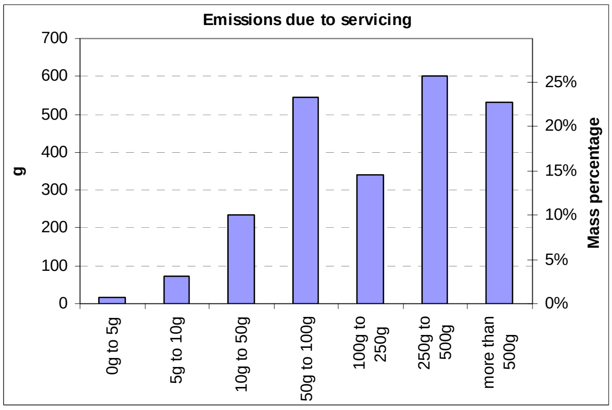


Figure 2.25: Mass emission as a function of emission range due to servicing (overall sample).

Figure 2.24 presents the classification of operations as a function of emission range due to servicing for the overall sample composed of 45 operations. For 16 cases, representing 36% of the sample, small emissions have been observed: between 0 and 5 g.

A few charging operations (5 cases, 10%) are very leaky and lead to massive releases of refrigerant (over 100 g).

- A large number of cans equipped with valve as well as some charging guns for S&P type (F1-13 illustrated in Section 1) are very leaky and are not very convenient to use. The valve is very leaky and it is frequent to see liquid refrigerant released at the connection when the can is put upside down.
- When the operator is using 2 or more small cans of "screwed type", the release of refrigerant remaining in the first can is sometimes significant, when the can is not empty (filling in vapor phase, without shaking).

Figure 2.25 illustrates the emissions during servicing classified by emission ranges. Emissions from 0 to 10 g represent 54% of the sample. In contrast, these emissions represent only 4% on mass basis of the total mass emitted during the charging process.

The major part of emissions (64%) is due to large releases, over 100 g, which represents only 5 cases of the sample. One non-correct operation done without care could release as much as 20 correct operations. 33% of the overall mass emissions range between 10 and 100 grams. Refrigerant emissions during charging process, which lead to a mass loss larger than 50 g, represent nearly 86% in mass of the total refrigerant emissions, but only 26% of the sample. The total mass emitted due to servicing represents nearly 16% of the sum of the refrigerants charged inside AC systems.

Can heels

At the end of the charging process, the refrigerant remains inside the can (valve equipped) or is released to the atmosphere if the charging kit is unscrewed (S&P cans). Depending on the charging process (shaking or not the can, filling the AC system in liquid or vapor phase) the refrigerant heel in the can is significant or not.

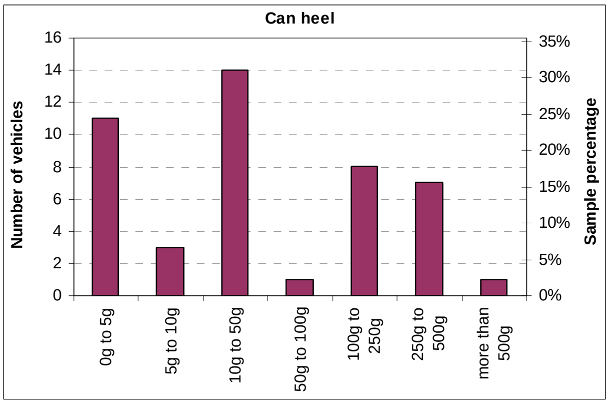


Figure 2.26: Number of vehicles as a function of can heel range (overall sample).

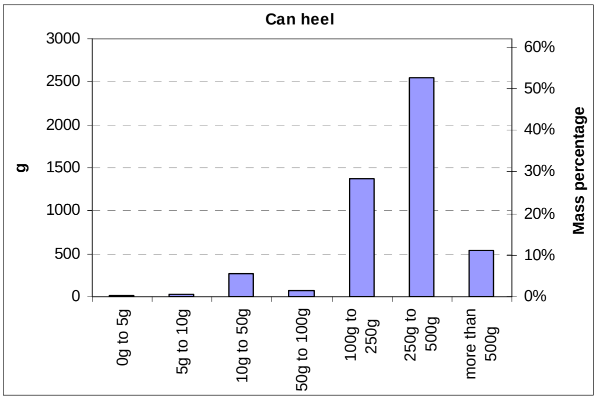


Figure 2.27: Mass emission as a function of can heel range (overall sample).

When the charging process is correctly done, the can is more likely empty at the end and the heel is low (between 0 to 10 g). This represents 31% of the operations that meet sensibly the number of persons who did correctly the operation (32%).

62% of the operations are done with can heel lower than 50 g, which represent only 7% of the total heel (see Figure 2.27). 38% of operations are not properly done (can heel is larger than 50 grams) but represent more than 90% of the overall can heel. The total heel resulting represents nearly 33% of the sum of refrigerants charged inside AC systems.

Overall refrigerant emissions

Figures 2.28 and 2.29 illustrate the total refrigerant emissions coming from emissions due to servicing as well as from the can heels after charge, measured during the 45 operations performed by small can users.

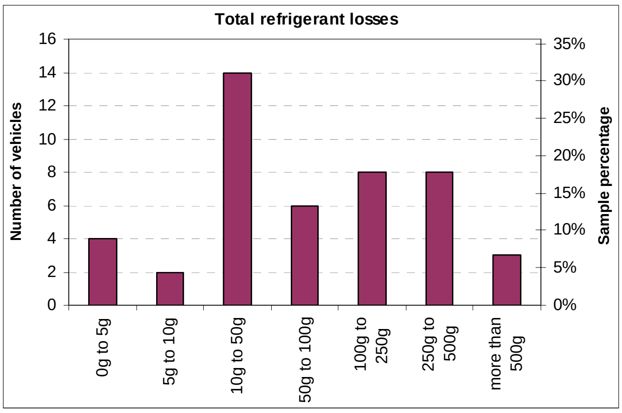


Figure 2.28: Number of vehicles as a function of total refrigerant emissions (overall sample).

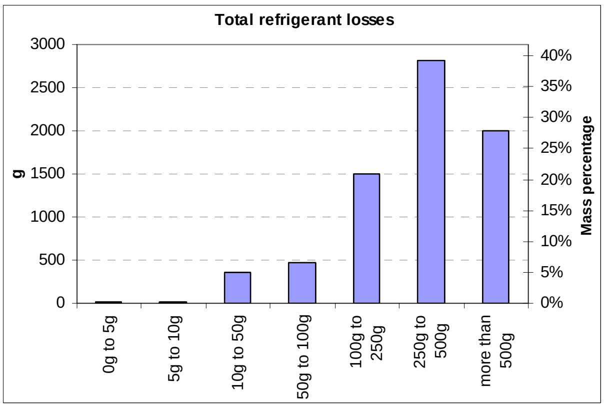


Figure 2.29: Mass emission as a function of total refrigerant emissions (overall sample).

Refrigerant emissions lower than 10 g represent (13% of cases) and lead to a total refrigerant release lower than 1% on mass basis (see Figure 2.29). Large releases of refrigerant (larger than 250 g per operation) represent 43% of the sample observed (45 vehicles and small can users), but represent 78% on mass basis.

Refrigerant mass repartition and ratios

Sample 1 (25 cases)

In Sample 1, the total mass of refrigerant contained in small cans before charging operation is 14,395 g, corresponding to an average value of 575 grams per vehicle. The effective refrigerant mass charged in vehicle is 8,557 g (342 g/vehicle) and represents 59% of the total initial mass. In contrast, the total refrigerant emissions due to servicing are 1,830 g (73 g/vehicle) representing 13 % of the total initial mass. Moreover, the total can heel is 4,009 g (160 g/vehicle), which represents 28% of the total initial mass (see Figures 2.30 and 2.31).

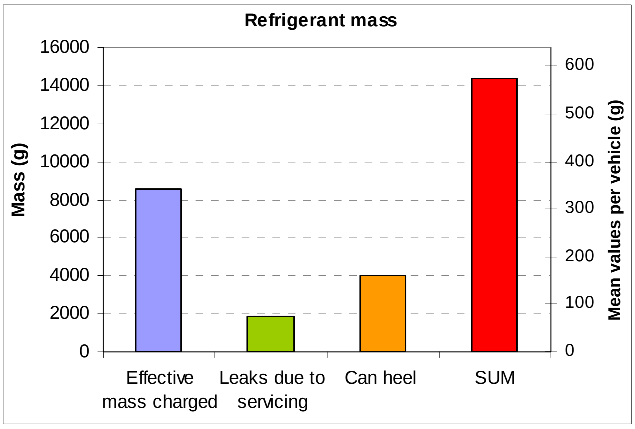


Figure 2.30: Refrigerant mass repartition (sample 1).

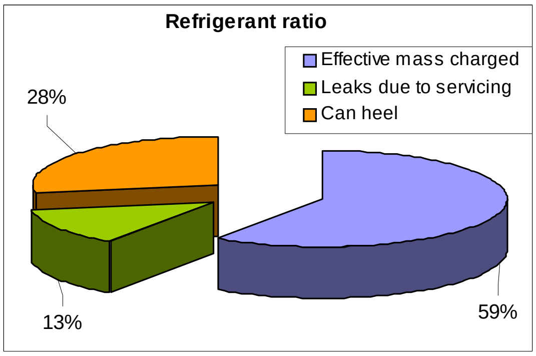


Figure 2.31: Refrigerant ratio (sample 1).

From the first sample, it could be concluded that DIYers who are non-familiar with small cans lead to overall emissions of about 68% of what has been charged inside the MVACS.

Sample 2 (20 cases)

In contrast, when the DIYers are familiar with small cans, the overall emissions are about 21% of the effective mass charged.

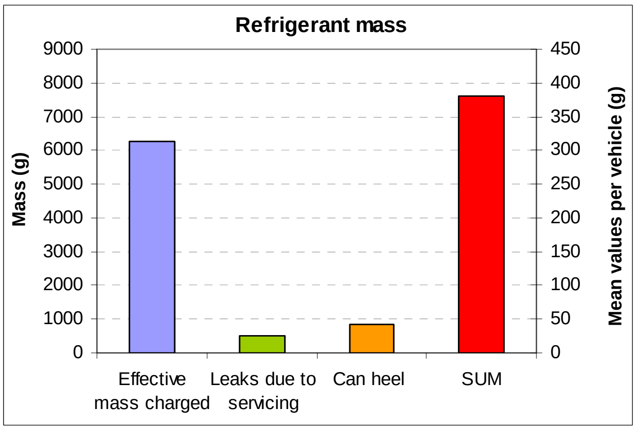


Figure 2.32: Refrigerant mass repartition (sample 2).

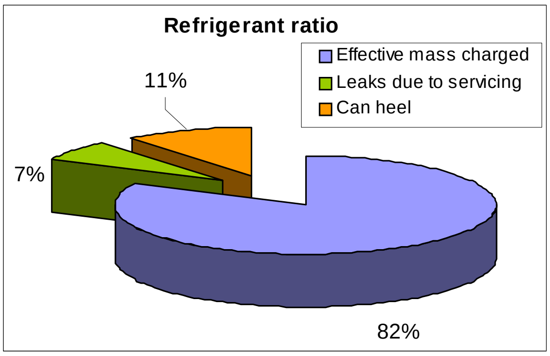


Figure 2.33: Refrigerant ratio (sample 2).

For sample 2, the total mass of refrigerant contained in small cans before charging operation is 7,626 g, corresponding to an average value of 381 g/vehicle. The effective refrigerant mass charged in vehicles is 6,280 g (314 g/vehicle) and represents 82% of the total initial mass. In contrast, the total refrigerant emissions due to servicing are 512 g (25 g/vehicle) representing 7% of the total initial mass. Moreover, the total can heel is 834 g (41 g/vehicle), which represents 11% of the total initial mass (see Figures 2.32 and 2.33).

Overall sample (45 cases)

Considering the overall sample, that covers a wide range of randomly chosen people, the values obtained are in a mid distance between those obtained for Samples 1 and 2. The overall emissions are about 48% of the effective mass charged.

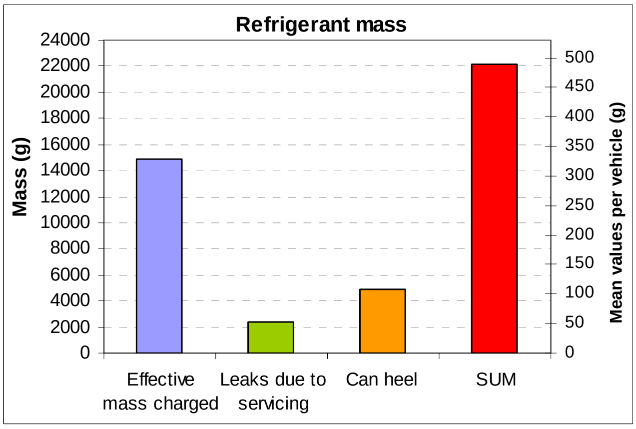


Figure 2.34: Refrigerant mass repartition (overall sample).

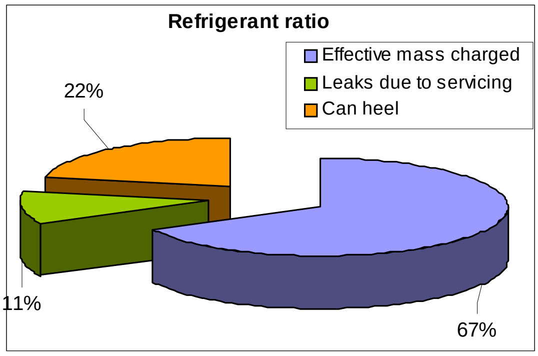


Figure 2.35: Refrigerant ratio (overall sample).

The total mass of refrigerant contained in small cans before the charging operation is 22,021 g, corresponding to an average value of 490 g/vehicle. The effective refrigerant mass charged in vehicles is 14,837 g (330 g/vehicle) and represents 67% of the total initial mass. In contrast, the total refrigerant emissions due to servicing are 2,341 g (52 g/vehicle) representing 11% of the total initial mass. Moreover, the total can heel is 4,842 g (108 g/vehicle), which represents 22% of the total initial mass (see Figures 2.34 and 2.35).

Values to be remembered

- 67% of initial mass contained in the cans are effectively charged into the system,
- 11% are directly emitted during the charging procedure,
- 22% remain in the can and constitutes the heel. They will be released to the atmosphere, sooner or later.

2.4 Lessons learnt from the field study and recommendations

The field work to study the habits of DIYers, when charging their MVAC system with small cans, has been a learning process in order to define the best possible methodology.

At the beginning, the CEP team thought it was possible to interest customers coming to auto-parts dealers to charge their own MVAC system by offering free small cans.

Because such a method has not been agreed by the auto-parts dealers, the CEP team began interviewing customers in order to know how they proceed to recharge their MVAC system.

In a second step, the CEP team, having its own car, has requested customers of those stores to help them charging the MVAC system. The MVAC system of the CEP vehicle was charged with refrigerant before the process, the refrigerant charge was noted, and so the emissions due to operation and can fills can be measured.

A third mean has been proposed by ARB: it was proposed to ARB personnel to obtain a free recharge of the MVAC of their car, providing that they make the recharge on their own vehicle in an ARB garage. This sample includes 16 people. For each and every vehicle, the remaining charge has been measured before the operation.

A fourth sample of 20 people has been constituted, using another CEP vehicle. All recharge operations have been carried out in the Los Angeles area. Nearly all people had previously made a refrigerant charge in an MVAC (no beginners).

For the studied sample of DIYers, 2/3 of the refrigerant has been charged in the MVAC system 1/3 has been emitted.

The main drawbacks associated with non-professional servicing are:
- Recharge without knowledge of remaining refrigerant and of the reference charge
- Recharge without leak search
- Recharge without recovery
- Wrong recommendations written on the can or the pressure gauge of the charging kit

First recommendations

The reference process for recharging an MVAC requires first knowing where the system is leaking. Leak search with hand leak detectors in vehicle under-hood is a difficult operation except for heavy leaks (leak > 10 g/yr). Leak search by hand leak detector cannot be done by DIYers. The use of dyes associated with UV lamps can be a solution for DIYers, providing the UV lamps be available at auto-parts dealers allowing end-users to check the leak tightness. If a heavy leak is discovered by the dye, the system has to be repaired by professional servicing.

Correct operation for recharging MVAC requires recovery of the refrigerant left in the system. It is an open issue to conclude that only professional servicing can operate Recovery and Recharge (R&R) machines.

If small cans were to be authorized, recharge with only the smallest can (12 oz.) can minimize emissions due to servicing by DIYers.

The tag displayed on small cans has to be changed. The following recommendations have to be mentioned and some have to be cancelled:
- the engine has to be set ON
- the MVAC has to bet set ON and at maximum air flow rate
- indications given by gauges mounted with the charging kit (as indicated by the report indication on dedicated pressure gauges are all misleading) have to be removed
- the interest of shaking the can for efficient charge has to be explained
- the way to stop the process and allow making sure that the can is empty has to be explained: no noise coming from the liquid, and temperature raise due to the end of the liquid evaporation.

It is necessary to have a general view of servicing either by professional or by DIYers to make adequate decisions (see General Conclusions).

3. Analysis of current leak search and recharge by professional servicing in California

3.1 Introduction

The aim of this section is to analyze the refrigerant leak search as well as the recharging procedure applied by professional servicing in California. In fact, a consumer unfamiliar with auto servicing, whose MVAC system presents a partial or full failure, will mandate a professional in order to repair it.

A MVACS failure on a CEP car will be simulated, consisting usually in an empty or partially empty system. The overall professional procedure will be described step by step from the preliminary AC check until the charge of the system. The operating mode of the service technician will be carefully described. After the charge, the CEP team will recover carefully the refrigerant in order to evaluate the accuracy of the recharge compared to the original system charge.

50 garages or AC repairs will be considered in different areas in California in order to cover a wide range of cases. Garage visits and operations are detailed in Appendix C.

3.2 Operating procedure to perform professional servicing analysis

3.2.1 Simulation of AC failure

A first proposal was to use rental cars to proceed and analyze the current professional servicing. Due to regulations, the CEP team was not allowed to use such vehicles and to operate on the AC system.

The first two operations were done using the Cadillac CEP (M&S) car. The CEP team was obliged to change this Cadillac for the following reasons:

- As mentioned previously, the Cadillac AC system ran originally with R-12 refrigerant and had been retrofitted to R-134a
- Two leak were detected, the first one on the HP service valve, the other on the suction port of the compressor
- After visiting two garages, the compressor clutch did not work any longer.

Note: one professional declined to make any repair on this system (because of the retrofit from R-12 to R-134a); thus, when a professional declines, the only way for charging such a system is to use small cans.

For this reason, the CEP team had to buy a vehicle running on R-134a. All other visits (48 visits) at professional garages have been made using the CEP Mitsubishi Montero car.

Two criteria have motivated the choice of the Mitsubishi. The first and main criterion is the accessibility of the high and low pressure servicing valves. The second one is that the Mitsubishi Montero offers a large cargo space that has been used to carry the CEP necessary equipment.

In order to ask a mechanics for repairing the system a failure needs to be simulated. The failure organized by the CEP team simulates real operating defaults of the MVAC system. Two failures are considered and described below.

▪ The CEP team charges partially the MVAC system with refrigerant. The mean refrigerant mass charged is around 100 grams. The MVAC system does not present any leakage, rupture or malfunctioning. 43 cases are considered partially empty.

▪ The other 7 cases are similar to the first ones, but the system is emptied down to residual pressure equals to atmospheric pressure.

3.2.2 Description of the MVAC system used

The Mitsubishi Montero AC is a single-evaporator system using a thermal expansion valve with a parallel flow condenser and a fixed displacement compressor. The HP and LP service valves are easily reachable as shown on Photo 3.1. The arrangement of AC components is also indicated on Photo 3.1. A scheme of the Montero AC system is shown on Figure 3.1.

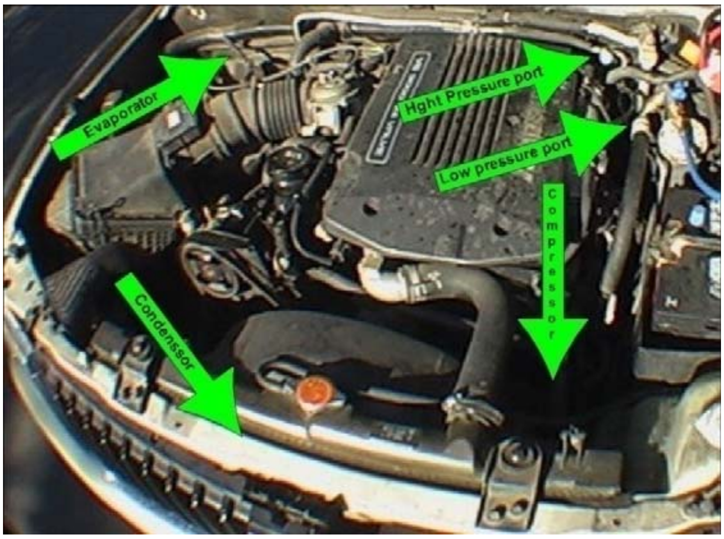


Photo 3.1: Under hood view showing the arrangement of the AC system components.

The potential leak sources on the Montero AC system are circled in red on Figure 1.1 and are as follows:

- The compressor rotating lip seal
- The suction and discharge ports of the compressor
- The inlet and outlet of the condenser, evaporator, and TXV
- The inlet and outlet of the liquid receiver
- The HP and LP service valves
- Fittings on the suction line and on the liquid line
- The high pressure sensor
- The relief valve

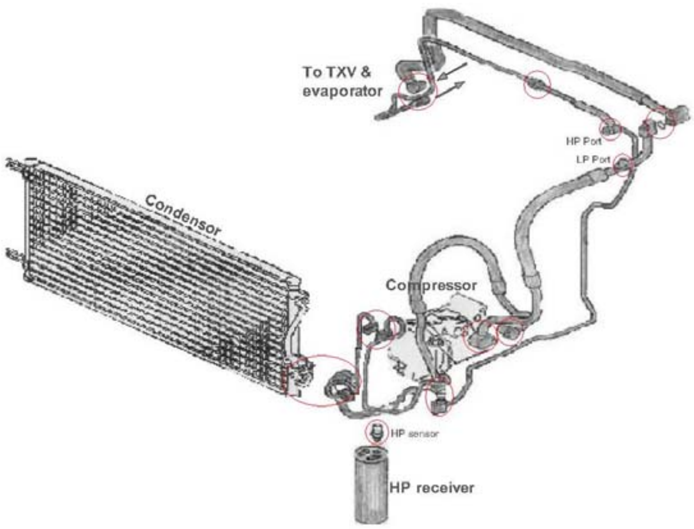


Figure 3.1: Schematic view of the Mitsubishi Montero AC system.

Using an electronic detector, the CEP team has performed a leak search on the MVAC system in order to check the system leak tightness. All parts and connections are verified. The whole system is tight, except at the TXV where a very small leak is detected.

3.2.3 Selection of professional garages and sample description

50 garages have been visited in California. Garages are located in different areas in order to collect a wide sample, especially in Los Angeles and San Diego (cf. Figure 3.2).

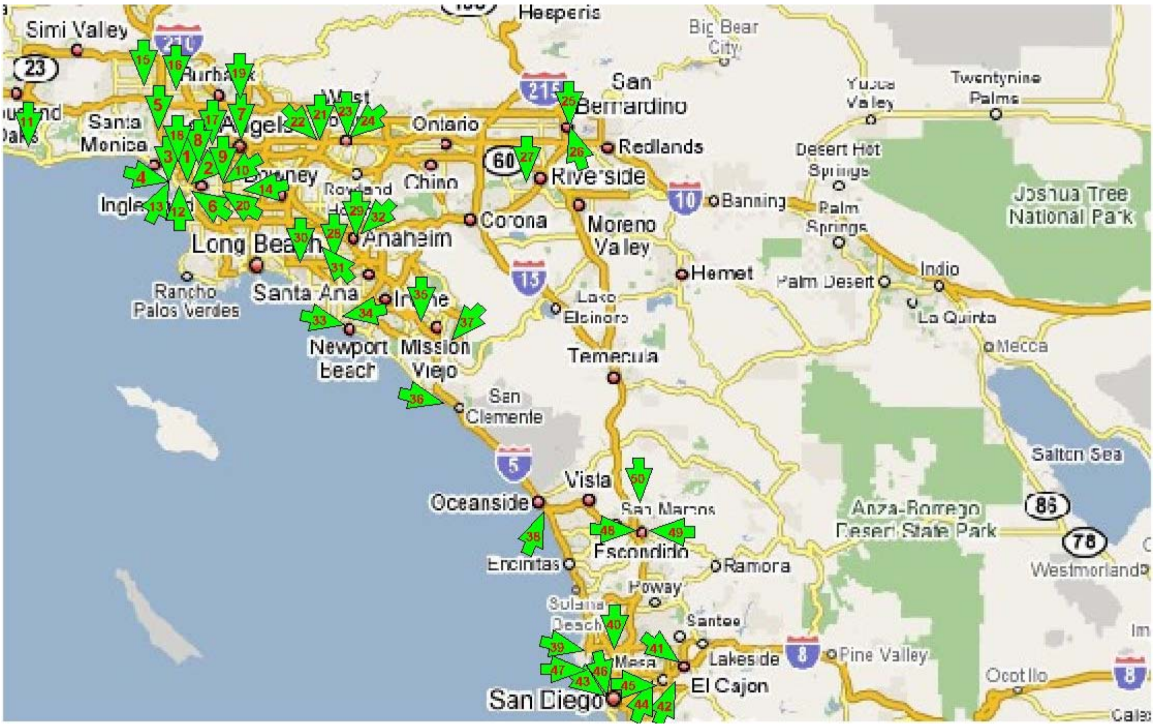


Figure 3.2: Location of garages visited in California.

Figure 3.3 shows the repartition of garages by size (technician number). 38% of garages consist of 2 or 1 technicians. 46 % have 3 or 4 technicians. The other 16% have 5 technicians or more.

N: Number of technicians

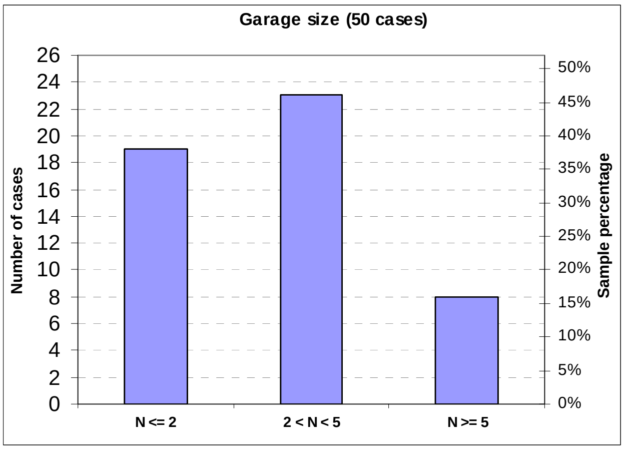


Figure 3.3: Garage sizes based on the number of technicians.

3.2 Analysis of current leak search and recharge by professional servicing

3.2.1 Preliminary AC check by professional servicing

Technician servicing makes usually a first AC check before any operation on the system. When the CEP team car is in the garage for servicing, the professional makes a preliminary AC check. The goal of this check is to make a first diagnosis on the failure cause. After this preliminary check, the technician servicing indicates a first diagnosis with a cost estimate. The client is subsequently free to accept or refuse the recommended actions.

This first check up could include:

- verification of the blown air temperature in the cabin,
- control of the compressor clutch,
- measurement of the low and high pressures (AC on),
- analysis of refrigerant using an electronic analyzer plugged on the service valves,
- verification of the pressure inside the AC loop by pressing the HP or LP valves.

Figure 3.4 illustrates the actions made by the professionals before doing any operation on the system (actions done before giving any diagnosis).

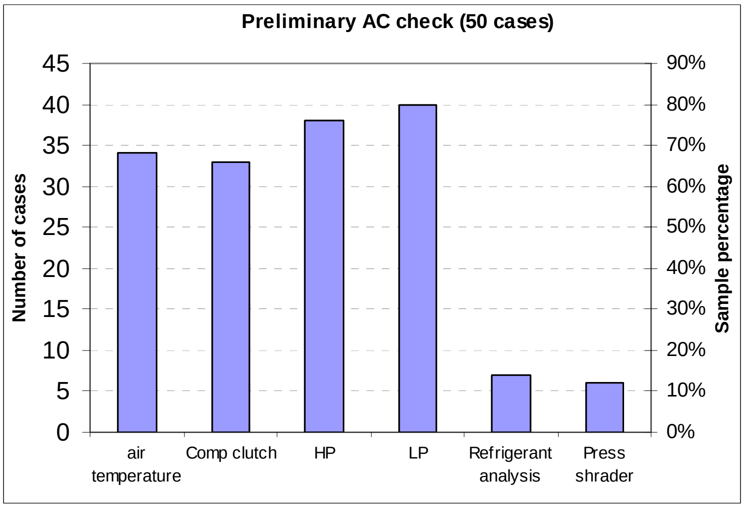


Figure 3.4: Preliminary AC check.

Note: several actions can be made by the technician (so percentages are only an indication of the most used method).

68% of professionals check immediately the blown air temperature in order to verify the availability of the fan and the coldness. 2/3 of professionals verify directly the compressor clutch by visualizing or by hearing that it is ON.

80% verify the low pressure and 76% verify the high pressure inside the system using a manifold when the AC is running. The difference between the two pressures in running mode (HP and LP) is an indirect way to check that the clutch is ON. In contrast, when the engine and the AC are OFF, the pressure check indicates if any refrigerant remains.

Other actions have been noted: the analysis of the refrigerant (7 cases), and pressing the Schrader in order to verify that refrigerant is released (6 cases). It should be mentioned that the preliminary AC check could combine two or more verification types.

After doing these preliminary checks, professionals give a first diagnosis (cf. Figure 3.5). The main recommended action to be performed was recharge of the AC system (94% representing 47 cases). In 34 cases the advice given to the CEP team was to check the leak tightness (68%). It should be noted that only 26 cases over 34 have verified the system tightness.

Three particular cases should be mentioned: 2 garages recommended to the CEP team to change the compressor (note: these two recommendations were made for the Mitsubishi). The third one recommended to buy small cans from an auto-part store and to recharge the AC.

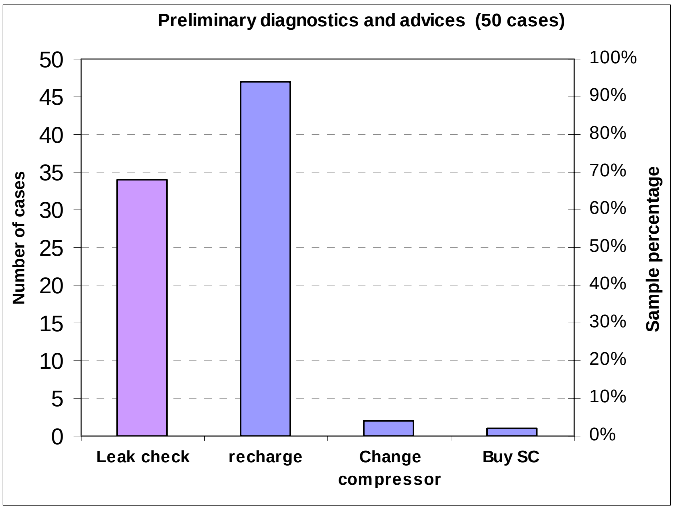


Figure 3.5: Preliminary diagnosis and recommendations.

3.2.2 Leak search and recharge by professional servicing

Depending on the diagnosis and the estimate given by the professional, the CEP team has then the choice to accept or decline the recommended actions.

When the professional is requested to operate on the vehicle, two evaluation steps are then performed. The first one is the leak search and the second one is related to the charging procedure.

Leak search procedure evaluation

Among the 50 technicians met only 47 have operated on the system. The three other cases are those who advised the CEP team to change the compressor or to buy SC from an auto-part store.

The CEP team noted that four groups of main first actions are performed when the servicing is accepted. These groups are classified as follows (cf. Figure 3.6):

- The technician releases the refrigerant to the atmosphere, evacuates the system and recharges it (4 cases)
- The technician recovers the refrigerant, recycles it with an automatic machine, evacuates the system, and recharges it partially or completely (24 cases),
- The technician keeps the system untouched with the remaining charge (7 cases),
- The technician adds refrigerant to the remaining charge done by CEP (13 cases).

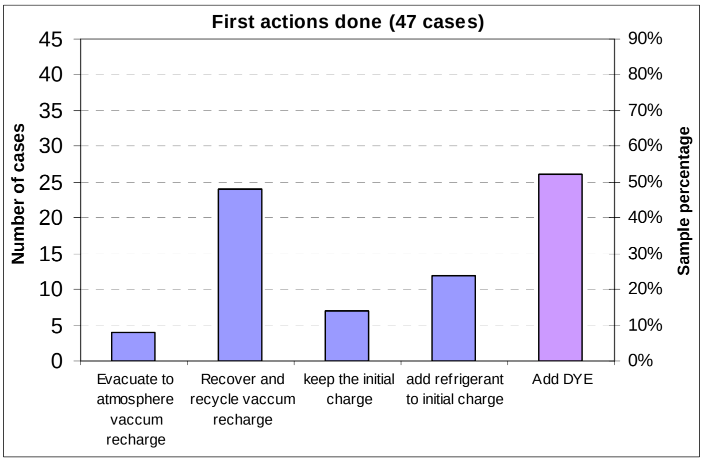


Figure 3.6: Small can users - Sample 1 description.

Whatever the method of operation, 26 technicians among the 47 have added DYE to the system using the automatic group or a special charging kit. In addition to the fact that those 26 technicians have added DYE, some of them did not perform the leak check. In fact, those technicians requested the CEP team to come back later for a leak search with fluorescent detector (20 cases).

Even though 34 technicians have recommended verifying the leak tightness as a first diagnosis, only 26 have performed the leak check (cf. Figure 3.7). In all cases, 5 methods are indicated:

- Controlling the rise of the vacuum pressure (7)
- Direct UV detection (22) including 3 technicians who noticed that the system was already charged with DYE
- Later UV detection (20)
- Electronic detection (14)
- Pressurized air or CO_2 with soap bubble (2).

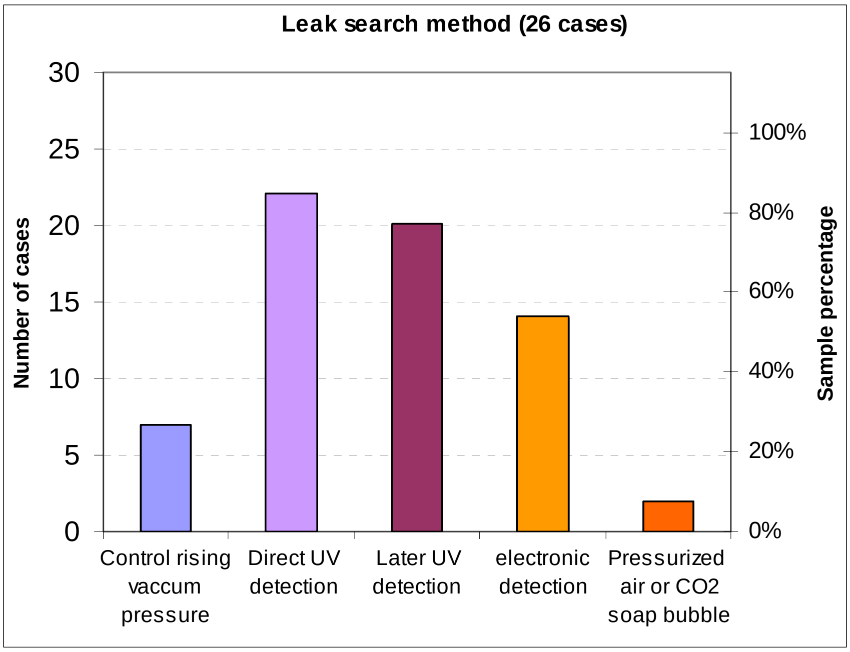


Figure 3.7: Leak search methods.

Note: technicians who used the soap bubble to detect the leak are those who filled the system with pressurized air or CO_2. The technicians who used CO_2 proceeded later with UV detection after releasing the CO_2 to the atmosphere, then charging with R-134a + DYE.

Several methods could be combined in order to verify the leak tightness of the system. When using an automatic charging machine, the pressure rise after evacuation is easily controlled (automatically). For UV detection, it is easier to add oil including DYE. An electronic check could be also done later on.

The leak search time is directly related to the good will of the professional who makes the servicing. If he spends more time searching leaks, the probability to forget potential leaks decreases.

2 technicians have performed careful leak search, spending the necessary time for that. 13 technicians have done it in less than 10 minutes. The 11 others took from 10 to 20 minutes (cf. Figure 3.8).

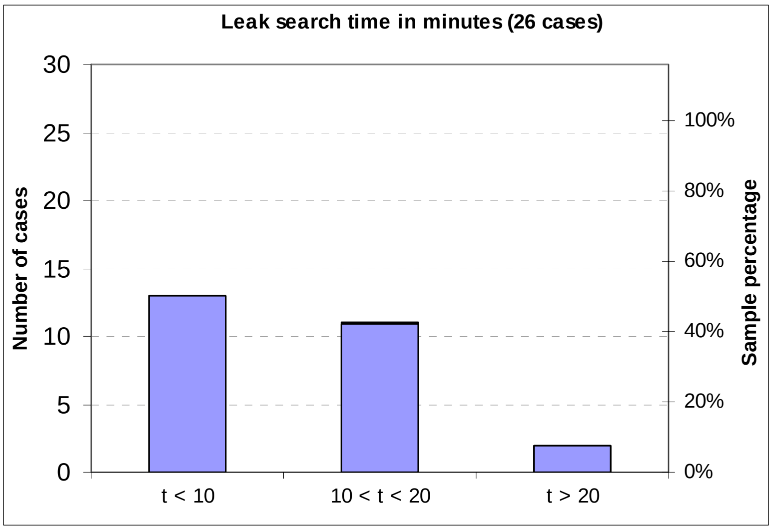


Figure 3.8: Leak searching time.

Among the 26 technicians who did the leak search, 8 of them have found leaks (cf. Figure 3.9). But the leaks found do not correspond to those detected by the CEP team at the TXV connection. In fact, most of the cases were traces of UV at several sites:

- 4 leaks were detected at the service valves,
- 3 leaks were detected at the suction line
- 1 leak on the condenser.

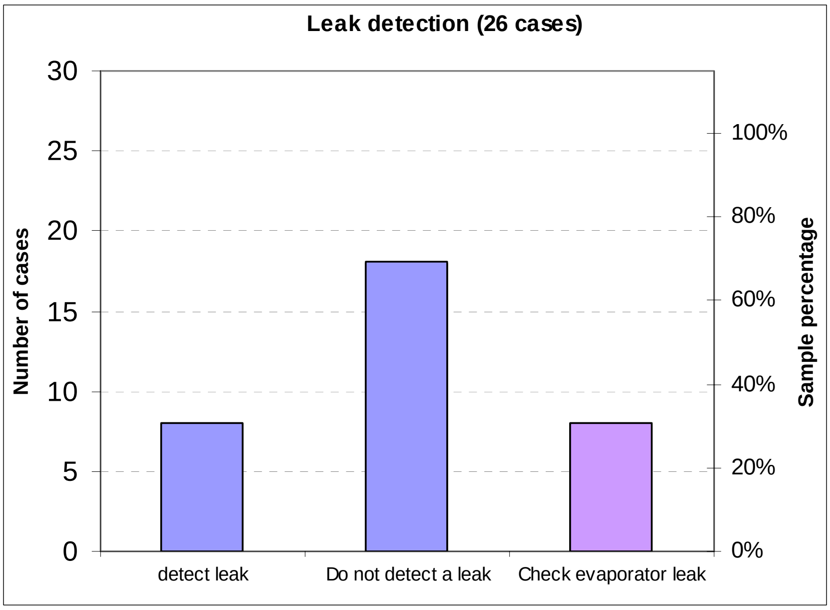


Figure 3.9: Leak detection.

Concerning the three technicians who found leak on the suction line, one of them advised the CEP team to change the complete line, the second one to change the seal of the fitting, while the third one, who found a leak on the suction port of the compressor, advised the team to change the line and the compressor. Of course, the CEP team declined doing that. The 20 other professionals did not detect any leak. None of the professionals detected the leak at the TXV.

It should be mentioned that 8 technicians have verified the leak tightness of the evaporator by opening the evaporator box.

Recharge procedure evaluation

Among the 50 garages considered at the beginning, 40 have charged the system with refrigerant. The 10 others, who did not charge the system, made the following comments:

- 1 technician said that the system was overfilled with oil (garage number 4)
- 1 technician advised to buy a SC (garage number 7)
- 3 garages, number 8, 11, 48, have given only advices
- 1 technician advised to buy a Schrader from an auto-part store (garage number 9)
- 2 technicians advised to change the compressor (garages number 22, 49)
- 2 technicians detected the leak at the suction line. The first recommended changing the line, the other one to change the suction seal (garages number 43, 40).

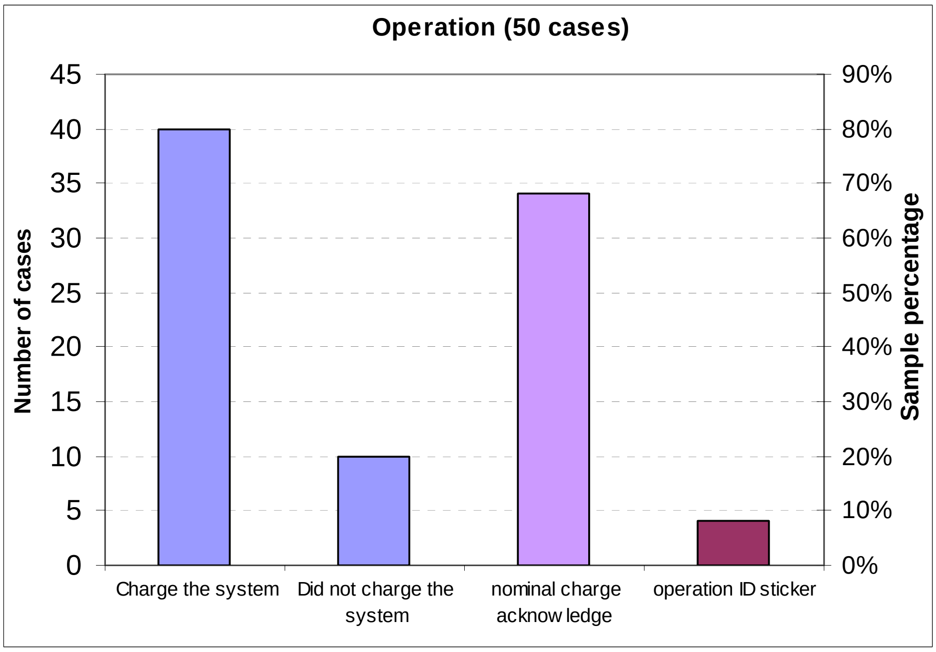


Figure 3.10: Recharge procedure.

Before charging the system with refrigerant, 34 technicians have read the nominal charge indicated by the manufacturer in the under hood. This information is crucial to be taken into account when the professional wants to charge exactly and properly the system.

An important point has to be mentioned: only 4 professionals marked their operation by putting a sticker in the under hood indicating the date of operation and the mass of refrigerant charged.

Three methods are used by professionals to charge the refrigerant in the system according to the equipment available in their garage.

- The use of automatic machine doing successively the recovery and the recycling, the evacuation and the charge. 29 out of the 40, who did the recharge, used automatic machines
- The use of refrigerant cylinder with manifold and vacuum pump. 13 have used this method, but not all of them have used the vacuum pump.
- The use of small cans to only charge the system, with neither recycling nor evacuation. In fact they only completed the charge (5).

40 technicians performed the refrigerant charge (see Figure 3.11). Two of them have made complementary charge with small cans, the first using automatic charging machine and the other using the cylinder and manifold. The first used the small can because he wanted to add a stop leak (4 oz.), the other one added oil (SC 12 oz. + oil).

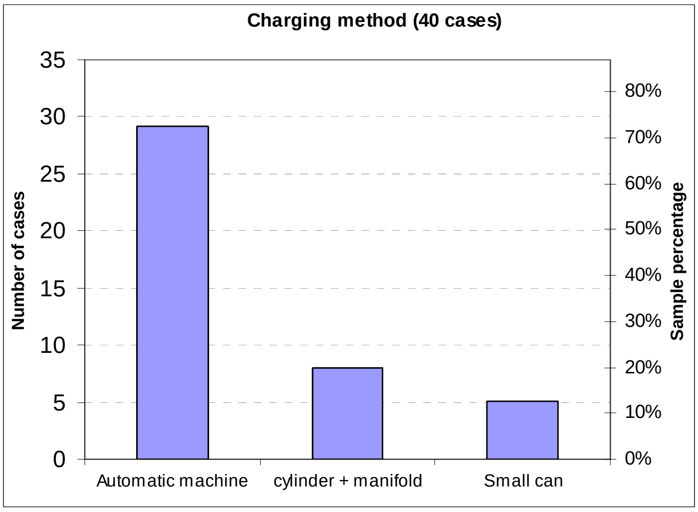


Figure 3.11: Charging methods.

26 technicians have added DYE when charging the system. 24 added oil to the system either by using an automatic machine or by injecting the oil directly with a specific charging kit. 1 technician has charged with a small can including a stop leak.

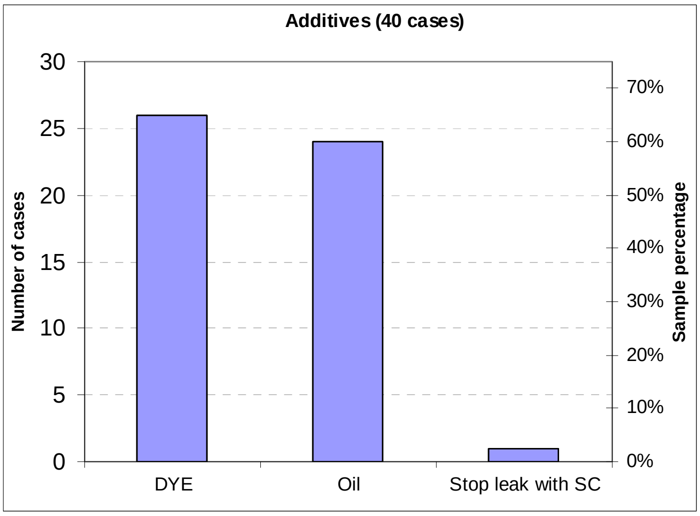


Figure 3.12: Additives.

In order to evaluate the refrigerant charges done by professionals and compare it to the original charge indicated by the manufacturer, after each visit, the CEP team proceeded to the precise recovery of refrigerant from the MVAC system.

The technicians who have charged are classified in four groups (cf. Figure 3.13).

- In blue those who charged with automatic machine
- In green those who charged with cylinder and manifold.
- In orange those who charged with SC
- In red those who combined two methods

Note:

the red line indicates the manufacturer nominal charge of the vehicle (680 grams). The 2 peaks shown correspond to the 2 cases performed with the Cadillac

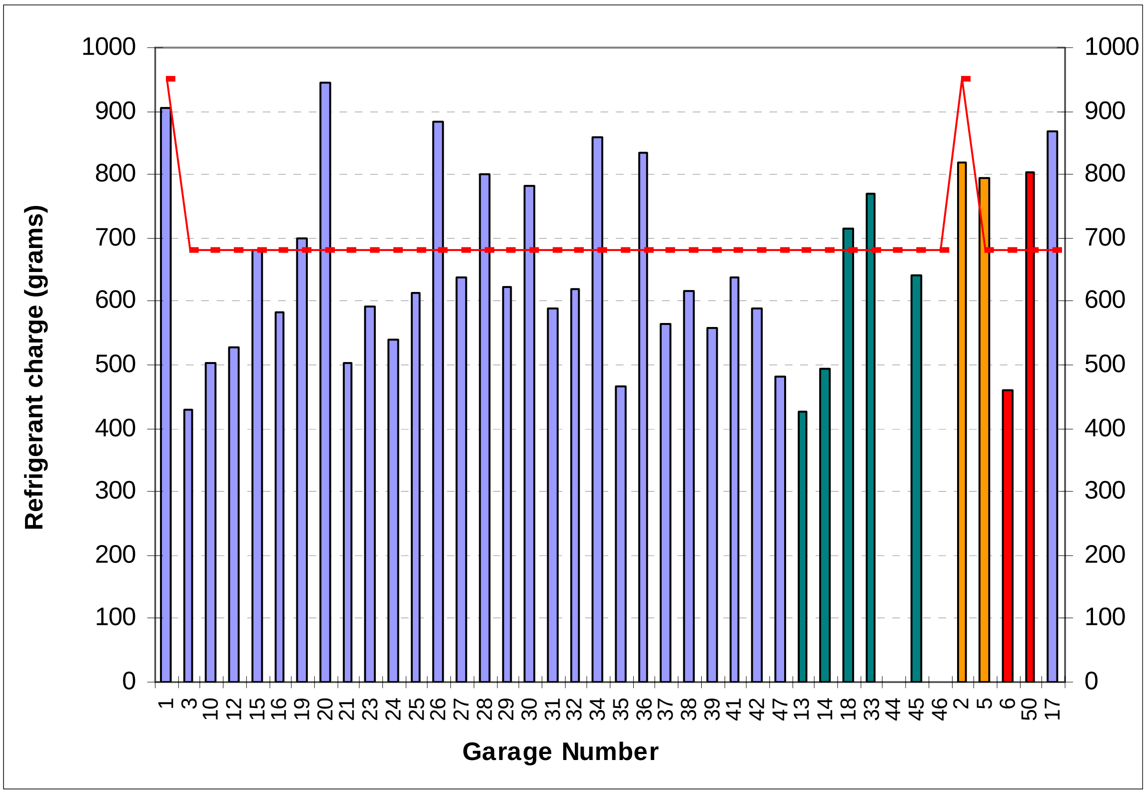


Figure 3.13: Refrigerant charge recovered for all professionals.

Figure 3.13 shows that most of refrigerant charges do not respect the nominal charge specified by the manufacturer, even when the charge is done with an automatic machine. The first reason is the precision of the automatic machine. The second reason is that some professionals do not respect the manufacturer charge even if they read it before.

Those who charged with cylinder combined with manifold, none of them has used a scale to weight the refrigerant charge.

Garage number 44 has released the charge to the atmosphere. Initially, the system was empty, so he charged the system without prior evacuation. The pressure increased when he ran the AC and the relief valve released the refrigerant. The same story occurred with garage number 46.

The summary of operations and actions during the 50 visits are presented in Figure 3.14.

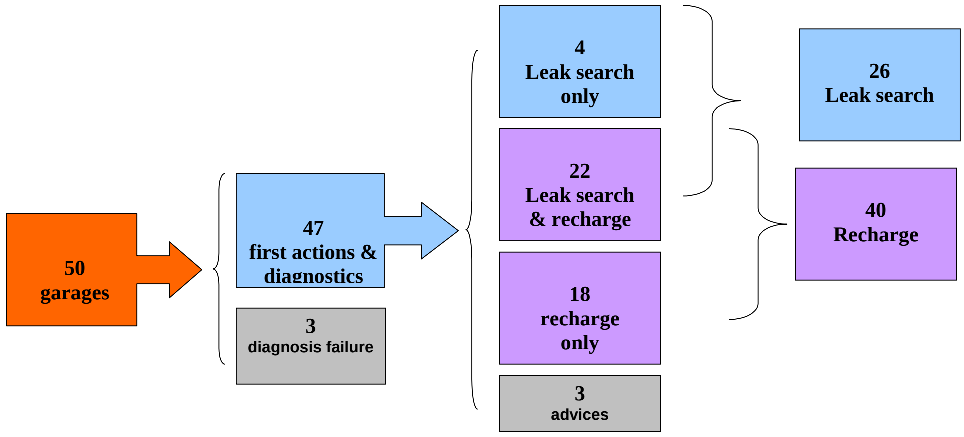


Figure 3.14: Operation summary.

Costs of professional servicing

Costs are summarized in Figure 3.15. It has to be mentioned that tests have been carried out during two successive campaigns, one in December 2007 and the other one in March 2008. In the two periods, the costs are "winter costs", and so lower than costs during the summer period.

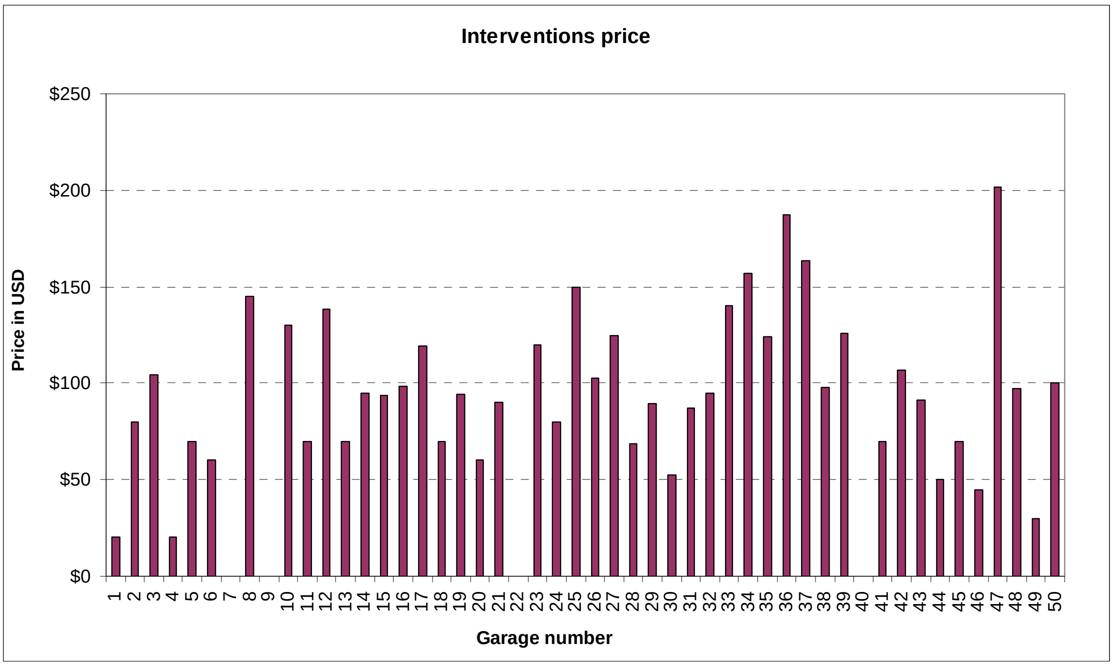


Figure 3.15: Prices as a function of garages and operation.

- For diagnosis only — Costs vary from 0 to 20 $
- For diagnosis + recharge with small cans or cylinders without leak search — Costs vary from 60 to 97 $ (average value on 9 cases **82 $**)

For all recharge with small cans or cylinders without recovery machine no leak search has been done.

▪ For diagnosis + recharge with R& R machine **without** leak search	Costs vary from 80 to 201$ (average value – 14 cases **121 $**)
▪ For diagnosis + recharge with R& R machine + leak search	costs vary from 53 to 204 $ (average value – 19 cases **113 $)**

Based on the sample, recovery recharge associated with leak search has been in the average cheaper by 7% compared to recovery and recharge without leak search!
Note: out of the 50 case garages, 8 have made either diagnosis only or wrong doing (see Appendix 3a).

3.3 Conclusions and recommendations

One of the purposes of the project was to compare emissions between the non professional and professional services. The methodology used in the study has led to evaluate quantitatively emissions due to DIYers, but it was impossible to apply the same methodology for professional servicing. The wrong doings (5 cases where the refrigerant has been evacuated to the atmosphere) have been acknowledged, but cannot be precisely evaluated quantitatively (around 200 g). When professionals use small cans, emissions can be seen as very low, also in the range of 5 g per operation. **The most important conclusion is that when professionals use R&R equipment, emissions are drastically reduced, in the range of 20 g per operation providing that the low pressure threshold of the recovery machine is set at 4 Psi abs.**

When comparing professional servicing and servicing by DIYers, it is essential to analyze the added value of professional servicing.

The possible added values of professional servicing are:
- correct diagnosis of failure
- efficient leak search
- use of recovery & recharge machine
- capability of repair.

How the diagnosis has been performed by the sample of professionals?

These first check-ups have included:
- verification of the blown air temperature in the cabin,
- control of the compressor clutch,
- measurement of the low and high pressures (AC ON),
- analysis of refrigerant using an electronic analyzer plugged on the service valves,
- verification of the pressure inside the AC loop by pressing the HP or LP valves.

Note: the temperature of blown air in the cabin is done by DIYers as well as professionals, the other ones requires expertise and equipment.

Professional servicing and leak search

26 technicians have performed the leak check using 5 methods:
- Control of the pressure rise after evacuation (7)
- Direct UV detection (22) including 3 technicians who noticed that the system is already charged with DYE
- Later UV detection (20)
- Electronic detection (14)
- Pressurized air or CO_2 with soap bubble (2).

Except leak search with dye, which can also be done by DIYers using small cans that comprise refrigerant + oil + UV dye, the other methods require expertise and equipment.

For the sample of professionals, none of the leak search with electronic leak detector has been successful (even if one slow leak was existing at the expansion valve), neither with other methods.

The lesson learnt by professional servicing on the necessary time lag between charging the dye and making a possible diagnosis of leak is confirmed by laboratory tests.

Professional servicing and R&R

About 2/3 of the professionals have used automated Recovery, evacuation and Recharge machine, which are essential for limiting refrigerant emissions during servicing providing that the recovery is performed down to 4 psi abs (see in previous pages). Nevertheless, even with automated machines, few professionals verify the original charge of refrigerant required by the car manufacturer.

Recommendations

- Systematic leak search before recovery when the saturating pressure is measured within the MVAC system
- Systematic use of R&R machines
- No recharge without verification of the original charge
- Stick a tag in the under hood indicating the recovery and recharge date.

Appendix 3a - Spreadsheet of the professional intervention

	Cost ($)	Intervention	Key errors			Refrigerant mass		Accuracy compared to manufacturer indication
			Prelyminary check & diagnosis	Leak search	Recharge	Before intervention	After intervention	
1	19.99	Diagnosis/Leak search/Recharge				257.9	905.1	-4.7%
2	80.00	Diagnosis/Recharge		Do not make a leak search	Do not put the MAC system under vacuum use small cans Do not put information under the hood about the intervention	222.7	819.7	20.5%
3	3.00	Diagnosis/Leak search/Recharge			Do not put information under the hood about the intervention	150.3	430.4	-36.7%
4	19.99	Diagnosis/Leak search			Do not read the manufacturer refrigerant mass Do not put information under the hood about the intervention	179.3	218.3	-67.9%
5	70.00	Diagnosis/Recharge		Do not make a leak search	Do not put the MAC system under vacuum Use small cans Do not put information under the hood about the intervention	88	793.3	16.7%
6	60.00	Diagnosis/Recharge	Push the schrader valve	Do not make a leak search	Do not read the manufacturer refrigerant mass Use small cans Do not put information under the hood about the intervention	158.7	460	-32.4%
7	130.00	Diagnosis	Advice to buy small cans in auto parts	Do not make a leak search	–	–	–	–
8	145.00	Estimated price		Do not make a leak search	–	–	–	–
9		Diagnosis/Leak search	Push the schrader valve	Evacuate the refrigerant to the atmosphere Do not check the leak on the evaporator compartment	Do not put information under the hood about the intervention	145.6	112	-83.5%
10	130.00	Diagnosis/Recharge		Do not make a leak search	Do not put information under the hood about the intervention	124.8	503.9	-25.9%
11	70.00	Estimated price		Do not make a leak search	Do not put the MAC system under vacuum Use small cans Do not put information under the hood about the intervention	108.9	–	–
12	138.18	Diagnosis/Leak search/Recharge			Do not put information under the hood about the intervention	108.9	527.6	-22.4%
13	70.00	Diagnosis/Leak search/Recharge		Do not check the leak on the evaporator compartment	Do not put the MAC system under vacuum Use cylinder Do not put information under the hood about the intervention	134.6	427.6	-37.1%
14	95.00	Diagnosis/Recharge		Do not make a leak search	do not put the MAC system under vacuum Use cylinder Do not put information under the hood about the intervention	102.7	494.4	-27.3%
15	93.97	Diagnosis/Leak search/Recharge			Do not put information under the hood about the intervention	83.3	680.8	0.1%
16	98.26	Diagnosis/Leak search/Recharge			Do not put the MAC system under vacuum	?	583.2	-14.2%
17	0.00	Diagnosis/Leak search/Recharge			Do not put the MAC system under vacuum Use small cans (oil) Do not put information under the hood about the intervention	95.6	866.8	27.5%
18	70.00	Diagnosis/Recharge		Do not make a leak search	Do not put the MAC system under vacuum Do not read the manufacturer refrigerant mass Use cylinder Do not put information under the hood about the intervention	119.3	715.9	5.3%
19	0.00	Diagnosis/Recharge		Do not make a leak search	Do not put information under the hood about the intervention	152.6	699	2.8%
20	60.00	Diagnosis/Recharge		Do not make a leak search	Do not read the manufacturer refrigerant mass Do not put information under the hood about the intervention	124	946	39.1%
21	89.90	Diagnosis/Recharge	Do not check the air blown temperature, compressor clutch & pressure (AC ON)	Do not make a leak search	Do not put information under the hood about the intervention	179.2	502.9	-26.0%

	Cost ($)	Intervention	Key errors			Refrigerant mass		Accuracy compared to manufacturer indication
22		Diagnosis	Push the schrader valve Bad diagnosis (change compressor & TXV)	–	–	–	–	–
23	120.00	Diagnosis/Leak search/Recharge			Do not put information under the hood about the intervention	93.6	591.2	-13.1%
24	80.00	Diagnosis/Recharge	Push the schrader valve	Do not check the leak on the evaporator compartment	Do not put information under the hood about the intervention	127.5	540.7	-20.5%
25	150.00	Diagnosis/Recharge		Do not make a leak search	Do not put information under the hood about the intervention	133.3	613.7	-9.8%
26	102.50	Diagnosis/Leak search/Recharge		Do not check the leak on the evaporator compartment	Do not read the manufacturer refrigerant mass Do not put information under the hood about the intervention	65	882.7	29.8%
27	124.60	Diagnosis/Recharge	Push the schrader valve	Evacuate the refrigerant to the atmosphere Do not make a leak search	Do not put information under the hood about the intervention	168	637.9	-6.2%
28	68.64	Diagnosis/Leak search/Recharge				134.8	801.6	17.9%
29	89.40	Diagnosis/Leak search/Recharge		Do not check the leak on the evaporator compartment	Do not put information under the hood about the intervention	107	623.4	-8.3%
30	52.33	Diagnosis/Leak search/Recharge		Do not check the leak on the evaporator compartment	Do not put information under the hood about the intervention	92.2	783.2	15.2%
31	87.41	Diagnosis/Leak search/Recharge		Do not check the leak on the evaporator compartment		151.9	588.5	-13.5%
32	95.00	Diagnosis/Recharge		Evacuate the refrigerant to the atmosphere Do not make a leak search	Do not read the manufacturer refrigerant mass Do not put information under the hood about the intervention	121.5	619.1	-9.0%
33	140.00	Diagnosis/Recharge		Evacuate the refrigerant to the atmosphere Do not make a leak search	Use cylinder Do not put information under the hood about the intervention	104.9	769.1	13.1%
34	157.05	Diagnosis/Leak search/Recharge		Do not check the leak on the evaporator compartment	Do not put information under the hood about the intervention	149	858.3	26.2%
35	124.08	Diagnosis/Leak search/Recharge			Do not put information under the hood about the intervention	102.7	464.9	-31.6%
36	187.38	Diagnosis/Leak search/Recharge			Do not put information under the hood about the intervention	112.2	834.8	22.8%
37	163.25	Diagnosis/Leak search/Recharge		Do not check the leak on the evaporator compartment	Do not put information under the hood about the intervention	101.9	563.9	-17.1%
38	97.66	Diagnosis/Leak search/Recharge			Do not put information under the hood about the intervention	99.8	616	-9.4%
39	125.64	Diagnosis/Leak search/Recharge			Do not put information under the hood about the intervention	81.4	558.6	-17.9%
40		Diagnosis/Leak search		Do not check the leak on the evaporator compartment	Do not put information under the hood about the intervention	98.8	82.6	-87.9%
41	70.00	Diagnosis/Recharge		Do not make a leak search	Do not read the manufacturer refrigerant mass Do not put information under the hood about the intervention	87.5	636.9	-6.3%
42	106.55	Diagnosis/Leak search/Recharge		Do not check the leak on the evaporator compartment	Do not put information under the hood about the intervention	87.6	589.5	-13.3%
43	91.03	Diagnosis/Leak search		Do not check the leak on the evaporator compartment	Do not put information under the hood about the intervention	102.9	0	-100.0%
44	49.99	Diagnosis/Recharge	Push the schrader valve	Evacuate the refrigerant to the atmosphere Do not make a leak search	Do not put the MAC system under vacuum Use cylinder Do not put information under the hood about the intervention	0	0	Evacue ce qu'il a chargé à l'atm
45	70.00	Diagnosis/Recharge	Do not check the air blown temperature & pressure (AC ON)	Do not make a leak search	Use cylinder Do not put information under the hood about the intervention	0	642	-5.6%
46	45.00	Diagnosis/Recharge		Do not make a leak search	Do not put the MAC system under vacuum Use cylinder Do not put information under the hood about the intervention	0	0	-100.0%
47	201.41	Diagnosis/Leak search/Recharge		Do not check the leak on the evaporator compartment	Do not put information under the hood about the intervention	0	480.7	-29.3%
48	97.32	Estimated price	–	–	–	–	–	–

	Cost ($)	Intervention	Key errors			Refrigerant mass		Accuracy compared to manufacturer indication
49	30.00	Diagnosis	Bad diagnosis (change compressor)	–	–	–	–	–
50	100.00	Diagnosis/Leak search/Recharge		Do not check the leak on the evaporator compartment	Do not put the MAC system under vacuum Do not read the manufacturer refrigerant mass Use small cans Do not put information under the hood about the intervention	0	804.6	18.3%

4. Laboratory tests simulating non professional operating modes in California

4.1 Evaluation of potential leak sources of professional servicing

The aim of this section of the study is first to evaluate the potential leak sources of refrigerant while a professional is intervening on the AC system. The second purpose is to recommend a series of actions to be done in order to assure a proper and less leaky maintenance.

4.1.1 System performances related to refrigerant charge

The cooling performance change of one of the 5 MVAC systems studied in Section 1 is analyzed along a leaking process. A controlled slow leak is simulated when the MVAC system is operating in steady state regime. The tests are performed at the CEP laboratory using its MVAC test bench (Photo 4.1).

Photo 4.1: General view of the test bench.

Photo 4.2: Leak valve with micro counter.

The leak is controlled by a precise valve with micro-counter (see Photos 4.2). The LFR is about 1.34 g/min. The leak is determined by weighting the recovered refrigerant in a cylinder connected to the low-pressure service valve. The leak process begins after reaching a steady state regime. When the steady state regime is reached, the leak valve is opened; leakage begins and continues until the degradation of performances (a very low cooling capacity, a very high superheat, very low evaporating and condensing pressures). The test leak process takes place during about 7 hours.
At the beginning of the test, the system is charged with 700 grams of refrigerant. The mass of refrigerant recovered 7 hours later is 130 g.

The temperature is maintained at 30°C at the inlet of the evaporator. The air temperature equilibrium at the inlet of the condenser is 33°C. Tests are performed at 1000-rpm compressor speed; the air mass flows on condenser and evaporator are respectively 420 and 1540 m^3/h.

Figures 4.1 and 4.2 show respectively the condensing pressure and the sub-cooling changes as a function of the refrigerant charge.

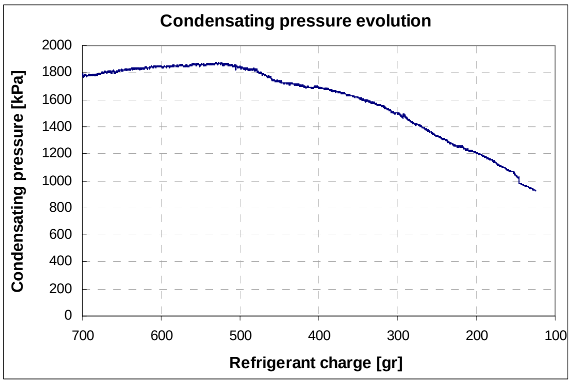


Figure 4.1: Condensing pressure evolutions.

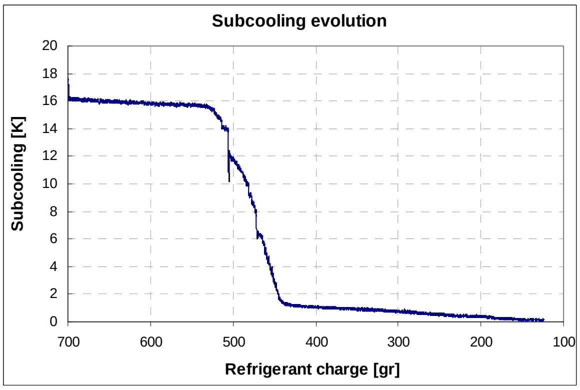


Figure 4.2: Sub-cooling evolutions.

Figures 4.3, 4.4 and 4.5 show respectively the evaporating pressure, the superheat, and the supply air temperature changes as a function of the refrigerant charge.

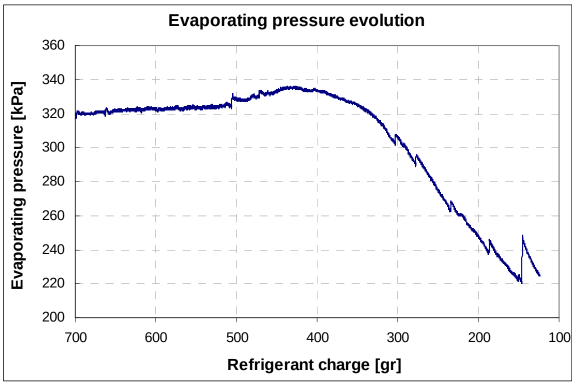


Figure 4.3: Evaporating pressure changes.

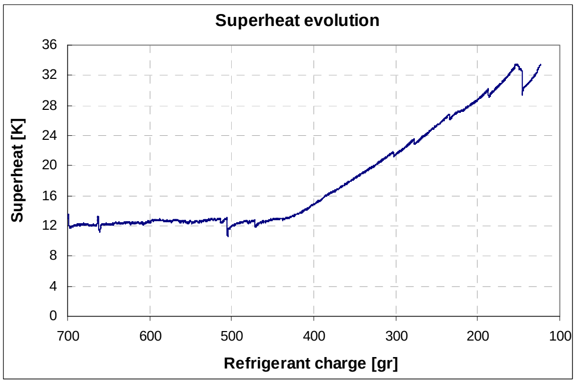


Figure 4.4: Superheat chnages.

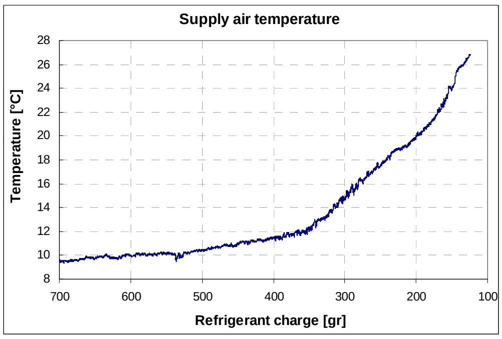


Figure 4.5**:** Blown air temperature changes at the evaporator outlet.

As it can be seen on Figures 4.1 to 4.5, three phases could be considered:

- The first phase corresponding to a system charge varying from 700 to 520 grams
- The second phase corresponding to a system charge varying from 520 to 340 grams
- The third phase corresponding to a system charge varying from 340 to 130 grams.

The first phase corresponds to the case where the liquid receiver still contains refrigerant in liquid phase whatever is the remaining quantity. In this case, the system performances remain constant independently of the refrigerant quantity. All properties are unchanged and especially the cooling capacity.

The second phase corresponds to the case when there is no liquid remaining in the receiver, sub-cooling is fairly small. It has to be noticed that the sub-cooling decreases along the leaking process (cf. Figure 4.2). The superheat increases linearly (cf. Figure 4.4). The air temperature at the evaporator outlet increases slightly (cf. Figure 4.5), meaning that the user or the mechanics cannot make the diagnosis that refrigerant is missing in those temperature conditions.

The third phase is reached when the refrigerant charge is low. The heat exchangers are then oversized, and the condensing pressure decreases. The mass flow rate decreases at the TXV. The superheat and air temperature at evaporator outlet increase rapidly. The need for refrigerant recharge can be assessed by the level of temperature.

The system tested is equipped with a thermostatic expansion valve (TXV) and a fixed displacement compressor working in a steady state regime. For MVAC system equipped with an Orifice tube expansion valve (OT), the variations of pressures are more sensitive to the refrigerant charge, especially during the first phase.

Concerning the user, the only parameter to evaluate the operation of the system is the blown air temperature. According to Figure 4.5, no significant changes of the blown air temperature can be detected before losing about 50% of the refrigerant charge (340 grams).

4.1.2 Potential leak sources during a classical maintenance procedure

During a classical maintenance procedure performed by a technician, potential emissions are related to:

- connection and disconnection of the recovery equipment to the service valve
- connection and disconnection of the charging cylinder or small can
- rough verification of refrigerant charge by triggering the service valve
- direct evacuation of the MVAC system without recovery
- emissions, when dismounting a component if the recovery procedure had not been accomplished properly.
- evacuation by the vacuum pump after refrigerant recovery.

The first operations, done on the system by the sample of professionals, could be divided in four cases (see also Figure 3.15):

- Direct use of automated recovery machine, which recovers, recycles, evacuates, and recharges the MVAC system (48% of the visited garages and 2/3 of those having recharged the system)
- Topping up refrigerant to the original charge usually using cylinder + manifold or small cans (24%) without leak search
- Searching the leak first (14%)
- Direct evacuation to the atmosphere before recharge (8%).

For most of the cases (43), the remaining refrigerant was sufficient to keep the saturating pressure of R-134a of the MVAC system, all technicians having recovered the refrigerant before making a leak search. This is clearly a wrong doing because the driving force of the leak is the refrigerant pressure inside the MVAC system, and so leak search has to be made up front. When the leak search is made after Recovery, evacuation and recharge, if the leak is found and the repair to be done, consequently the evacuation is made twice entailing undue release of refrigerant to the atmosphere.

Service valves

In fact, each time the service valves are used a leak occurs. The refrigerant quantity released is random and depends on the professional actions and equipment used. The leak is estimated usually in between 2 to 5g. Undue verification of refrigerant pressure by pushing the Schrader mechanism of the service valve may lead to emissions up to 10 to 15 g.

When a professional connects recovery equipment or cylinder using a quick coupler with moving rod, the emissions are usually lower compared to connections fastened with fixed rod. Photo 4.3 shows a quick coupler with a moving rod. When turning the valve, the rod moves to push the Schrader valve of the service valve. The leak tightness is ensured before the Schrader is pushed down and so make the connection. In fact, these connections are connected first to the service valve and then the gates are screwed and opened.

In contrast, the quick couplers with a fixed rod open the gates at the moment they are connected. Photos 4.4, 4.5 and 4.6 show three types of quick coupler with fixed rod fastened with clips.

Photo 4.3: Quick coupler - Connection with moving rod by screwing fastened with clips.

Photo 4.4: Quick coupler - connections with fixed rod fastened with clips equipped with ball valve.

Photo 4.5: Quick coupler - connections with fixed rod fastened with clips.

Photo 4.6: Quick coupler - connections with fixed rod fastened with clips.

For couplers with fixed rod, the tightness of the operation is random and depends on the skills of the technician operating on the system. If the Schrader valve is pushed straightly, the valve will not leak or at a lesser extent. In contrast, if the Schrader is wrongly pushed, it will leak unexpectedly.

Clearly, the couplers with moving rod are less leaky. The coupler is first fixed on the service valve, the valve is then turned in a way to move down the rod and open the gate. The professional could check the way the valve is installed before opening the Schrader.

The charging method

The charging method is a potential source of refrigerant leak. As shown in Section 3.2.2, three methods can be used by professionals to charge a MVAC system:

- with automated machines (represent 72.5%)
- charge with cylinder + manifold (20%)
- charge with small cans (7.5%).

Usually, the automated machines perform the whole procedure without action by the professional (recovery, evacuation, leak test, and recharge). The machine is connected to the system via HP and LP service valves. The quick couplers used are usually with a moving rod, allowing thus good leak tightness. The connection between the machine and the system is set once.

Photo 4.7: Automated machine in service.

The major emission occurs at the connection valves (assuming that the machine is tight enough). Each time a hose is installed or removed, a small emission occurs. For this reason, the use of an automated machine leads to lower emissions because there are only 2 connecting actions on the HP and LP pressure service valves and 2 disconnecting actions, which are the lowest number of connecting / disconnecting actions.

Another conventional method consists in using successively :

- a recovery machine,
- a recovery cylinder,
- a manifold,
- a vacuum pump

Thus, the possible number of connecting/disconnecting actions could be as high as ten and so emissions are higher.

Photo 4.8: Recovery machine and cylinder.

Recovery efficiency and Evacuation

Whatever the method used, the recovery machine allows recovering refrigerant at a specified limit (~4.3 psi absolute). The remaining refrigerant in the system cannot be recovered and so it is released to the atmosphere when using the vacuum pump.

The vacuum pump releases the refrigerant or air remaining in the system to the atmosphere. The remaining quantity of refrigerant depends on the recovery pressure limit, temperature, and the system internal volume. **Typically this quantity varies from 10 to 100 g depending of the low-pressure threshold fixed (4.3 or 14 psi abs).**

4.1.3 Recommended service procedure

In fact, a user goes to a garage for MVAC servicing in two cases: his AC system is working poorly or not working at all. The reasons for such malfunctioning could be mechanical failure of the compressor or other components (evaporator blower, condenser fan, electronic command) or low refrigerant charge in the system. The professional should identify through inspection, the source(s) of malfunctioning before connecting any hoses to the service valves.

As mentioned in the MACS (Mobile Air Conditioning Society) report on "recommended air conditioning inspection and preventive maintenance procedures" [MAC05], the following steps have to be done leading to an efficient and effective operation:

- Inspect the coldness of blowing air
- Inspect the compressor drive belt and clutch
- Inspect the flexible hoses and metal lines for signs of leakage or damage
- Inspect the compressor for signs of possible shaft seal leakage
- Inspect and clean the front of the condenser
- Check operation of all fans, blowers, air filters, and air circulation
- Check the functioning of the heater control valve (if any)

Once the mentioned actions are performed without any observations indicating the failure cause, the professional can then operate on the system by measuring the pressure in order to confirm the presence of refrigerant.

1) AC OFF

In fact, when the AC is OFF, the pressure at the equilibrium phase is related to the ambient temperature and not to the refrigerant charge. In contrast, with a single phase presence the pressure is related to both: refrigerant charge and ambient temperature. When the pressure is lower than the saturation at the corresponding ambient temperature, that means the system is filled only with gas phase. To conclude, when the AC is OFF the system pressure indicates two cases:

- A partially empty system with gas phase (lower than saturation pressure or near atmospheric pressure).
- A partially or correctly filled system, when the pressure equals the saturation pressure.

So when the AC is OFF, the only conclusion which can be drawn from the value of internal pressure is associated to a system that is nearly empty (without any more liquid). It cannot indicate the quantity of refrigerant when any liquid phase is still in the system.

2) AC On

The measure of evaporation and condensing pressures indicates the functioning of the compressor. Moreover, it could be useful to estimate the refrigerant charge in the system by comparing the thermodynamic properties as shown in Figures 4.1 to 4.5.

Note: the only way to acknowledge the correct charge is to determine the sub-cooling: $Sb = T_{outlet\ condenser} - T_{sat}$ (condensing pressure), which requires not only pressure measurement but also precise temperature measurement at the condenser outlet.

To conclude

- If the AC failure does not concern the refrigerant system (e.g. fan, air circulation, belt…etc), the professional should not operate on the service valves.
- The first action concerning the refrigerant should be leak search **before recovery.**

- If the preliminary tests are carried out, the professional could then operate on the service valves in order to check pressures in standstill and in operation modes.
- To recharge the system, the lowest emissions during servicing are obtained when using an automated machine with quick coupler equipped with moving rod;
- The lower pressure threshold of the recovery machine low-pressure controller has to be set as low as possible (typically 4.3 psi abs.); many are set just under atmospheric pressure (10 to 14 psi abs)
- For heavy leak (> 40 g/yr), the rise of pressure after deep evacuation could be a correct method provided the oil is hot (T > 50°C) in order to avoid refrigerant outgasing from the oil.
- The leak search using either dye and UV lamp or electronic hand leak detectors are both acceptable methods (see Section 4.3), but only the wrapping method allows detecting practically leak in the range of 5 to 15 g/yr.
- In the presence of leak, the fluid is recovered in order to repair the leak. In absence of leak, the fluid is recovered and refilled with the appropriate refrigerant charge.

4.2 Leak tightness tests of brand new and after use small cans

4.2.1 Introduction

The reference technique for DIYers to recharge a MVAC system is to connect a small can to the system. The small cans are filled with refrigerant, currently HFC-134a, but may content lubricant, dye, and sealant. Both DIYers and professional technicians use these small cans.

This Section 4.2 is dedicated to the laboratory measurements of refrigerant emissions from small cans before and after a first use.

The LFR is measured using an infrared spectrophotometer that continuously records the rise of refrigerant concentration inside an accumulation volume where the can has been installed. The test method is identical to the one defined by the European Regulation 706/2007[EUR07].

The leaks of 15 can samples have been measured before and after a first use, at three different temperatures making in total 90 leak tests. Tests have been performed at the CEP laboratory. The tests show that refrigerant emissions depend strongly on the can and charging kit sealing technologies.

4.2.2 Description of small cans

A small can consists in a sealed casing containing a pressurized refrigerant that will be transferred to a MVAC system, by means of a valve and a flexible hose constituting the charging kit. This can is usually built by assembling three different metallic parts: a jacket, a valve plate, and a bottom plate. The can leak tightness is achieved by placing an elastomer seal between the valve plate and the jacket, as well as a rolled edge seal on the bottom plate (see Photo 4.9).

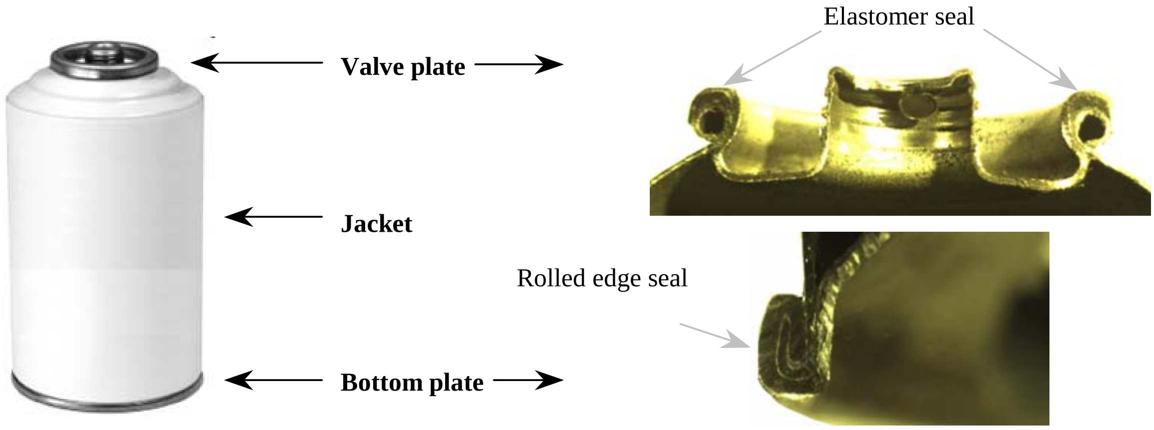


Photo 4.9: Small can main components.

The two families of small cans are defined by the valve technology:

- A self-closing valve inserted in the valve plate (type V, see Photo 4.10), or
- A valve that is screwed and perforates the valve plate (type S&P, see Photo 4.12).

The charging kits also include a flexible hose connecting the small can to the air-conditioning system. The flexible hose and its low-pressure fitting are not considered in this leak test study since they are free of refrigerant before and after a partial use.

The **self-closing valve** cans are available in 14 oz. and 19 oz. capacities. The self-closing valve is installed in the valve plate (see Photo 4.10) and tightened with an elastomer seal (see Photo 4.11). An actuator pushes the stem downward (see Photo 4.11) and the refrigerant is released to the flexible hose. When the user stops acting, the stem closes and the container remains sealed.

Photo 4.10: Valve plate with a self-closing valve.

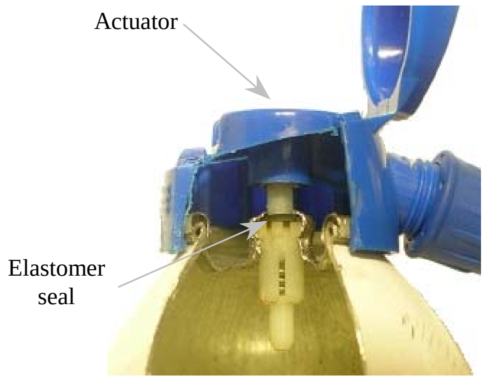


Photo 4.11: Sectional view of a self-closing valve actuator.

The **screwed and perforated** cans have a different valve plate that incorporates an externally threaded portion coupled with the valve plate (see Photo 4.12). This portion has a wall that will be penetrated by the pointer of a valve. The S&P cans are proposed in different capacities: 12, 13, 14, and 18 oz.

Two different valve technologies can be found in S&P cans:

- The shut-off valve, and
- The push button valve.

The **shut-off valve** is screwed on the can valve plate (see Photo 4.12). After that, the user turns the handle and the pointer moves downward and penetrates the valve plate wall releasing the refrigerant. To isolate the container, the user must continue turning the handle until the pointer reaches the maximum displacement and contacts the valve central body. Valve isolation is achieved by using an elastomer seal between the valve and the container valve plate, and a metal-to-metal contact between the pointer and the valve central body (see Photo 4.13).

Photo 4.12: Valve plate of an S&P can.

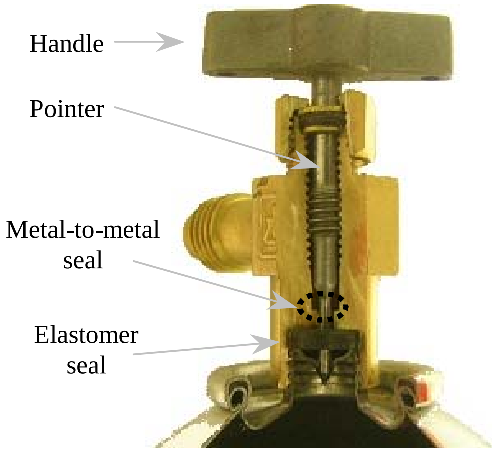


Photo 4.13: Sectional view of a shut-off valve.

The **push button valve** is also screwed on the can valve plate, but has a different perforating mechanism from the shut-off valve. As user screws the valve, a pointer penetrates the valve plate wall and the refrigerant automatically flows to the valve. The valve is tightened by using four different seals (see Photo 4.15). When the handle is squeezed, the refrigerant is transferred to the flexible hose and once the handle is released, the valve and the container are isolated.

Photo 4.14: Rubber seal and pointer of a push button valve.

Photo 4.15: Sectional view of a push button valve.

The seal is the weakest link not only of the refrigerant container, but also of the charging kit. Seal performance depends on different variables, such as the surface topography, the seal material properties, the seal design, and the applied load. Accordingly, it is expected that, as the number of seal increases, the refrigerant emissions also increase.

Table 4.1 lists a large variety of small cans and Table 4.2 of charging kits available on the Californian market. A list of small cans and their characteristics (their type, content, market price and on-line net price) is presented in Appendix A.

Table 4.1: Details of tested small cans.

Brand Name	Fitting type	Capacity (g)	Contents	CEP reference	Notes
A	Valve equipped	510	R-134a + lubricant + leak sealer	C1-01	No rolled edge seal
A	Valve equipped	510	R-134a + lubricant + leak sealer	C1-02	No rolled edge seal
A	Valve equipped	396	R-134a + lubricant	C1-04	
A	Valve equipped	397	R-134a + lubricant + leak sealer	C1-06	
A	Valve equipped	398	R-134a + lubricant	C1-07	
A	S&P	396	R-134a + lubricant + leak sealer	C1-03	
A	S&P	396	R-134a + lubricant	C1-05	
A	S&P	396	R-134a + lubricant + leak sealer	C1-08	
A	S&P	398	R-134a + lubricant + leak sealer	C1-10	
A	S&P	368	R-134a + lubricant + leak sealer	C1-13	
B	S&P	340	R-134a	C3-01	
B	S&P	340	R-134a	C3-02	
B	S&P	340	R-134a + leak sealer	C3-03	
C	S&P	538	R-134a + lubricant + leak sealer	C4-01	
C	S&P	538	R-134a + lubricant + leak sealer	C4-02	

Table 4.2: Details of tested charging kits.

CEP reference	Fitting type	Photo
F1-01	Valve equipped	
F1-02 F1-03 F1-04 F1-05	S&P S&P S&P S&P	
F1-07	S&P	
F1-09 F1-11 F1-12 F1-13	S&P S&P S&P S&P	
F4-02	S&P	

As indicated previously, two series of tests have been performed on the two families of small cans: the first series on the brand new small cans, and the second series after a first use of the small cans.

The S&P cans are cheaper than those with valve or valve plus pressure gauge. The S&P price varies according to the refrigerant content and the brand name. For this reason, people prefer to buy the charging kit for once and then re-use it with S&P cans. It has to be noticed that the S&Ps are dominant (nearly 90% of the market, as assessed by several dealers) for two reasons: the more knowledgeable DIYers buy S&Ps due to the easiness of use; less knowledgeable, but price-oriented DIYers are also choosing S&Ps. Users prefer to buy S&P cans since they are cheaper than valve-equipped ones and they can re-use the charging kit with others S&P cans.

4.2.3 Tests and results

The aim of this section is to evaluate the can leak tightness, before use (small can without charging kit) and after partial use (small can + charging kit), in order to verify if the can is tight enough to keep the remaining refrigerant in the can for a later use.

The CEP has developed a method for determining the annual leak flow rate for MVAC system components using infrared spectrophotometry [ACE05]. This method of test is consistent with European regulation 706 / 2007 [EUR07]. The leak flow rate of a can is measured in an accumulation volume (see Photo 4.16) by an infrared spectrophotometer. The rise of R-134a concentration is measured in the accumulation volume and translated in annual mass leak flow rate.

Photo 4.16: Accumulation volume where refrigerant annual leak is measured

Before leak tests, the infrared gas analyzer is calibrated using three different refrigerant concentrations: 0, 100, and 450 ppm. The cell volume is calculated using a calibrated leak (see Figure 4.6). The LFR measurement relative uncertainty is about 6%.

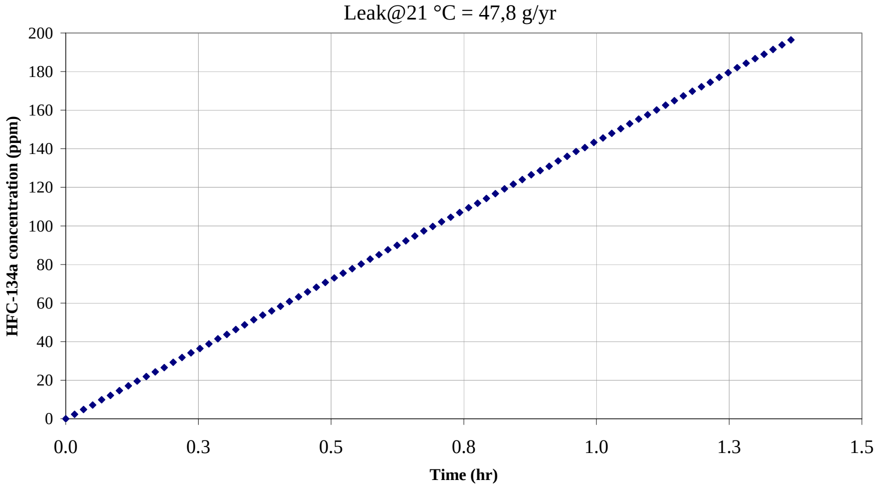


Figure 4.6: Rise of refrigerant concentration using a calibrated leak.

As shown in Photo 4.16, the can is installed inside a hermetic volume where ambient pressure and temperature are controlled. Measurement starts when the preset temperature is reached and the annual leak flow rate is calculated using only the linear evolution of the refrigerant concentration.

The measurement accuracy is better than 0.1 g/yr.

As shown in Table 4.3, tests have been performed on S&Ps as well as on V-type cans. The leak flow rates are determined before and after the use of cans. An S&P type can is considered new, when the can tap of the charging kit is not screwed on it. A valve-equipped type can is considered new, when it is intact as bought.

Table 4.3: Small can leak test results.

Small Can			Leak Flow Rate [g/yr]						
Net Weight [g]	Type	CEP Reference	new °C			used °C			
			30	35	40	30	35	40	Charging Kit
510	V	C1-01	3.17	3.88	5.28	3.41	4.05	4.79	F1-01
396	S&P	C1-03	0.11	0.19	0.32	0.19	0.28	0.55	F1-02
510	V	C1-02	0.83	1.24	1.95	0.86	1.24	1.65	F1-01
396	V	C1-04	0.62	1.03	1.73	0.55	0.86	1.51	F1-01
396	S&P	C1-05	0.37	0.60	1.05	441	526	714	F1-09
397	V	C1-06	0.97	1.59	2.27	0.70	2.08	3.34	F1-01
398	V	C1-07	0.66	1.09	1.64	0.75	1.14	1.84	F1-01
396	S&P	C1-08	0.39	0.62	0.97	1.52	2.23	2.60	F1-12
398	S&P	C1-10	0.41	0.62	1.09	3.09	4.48	5.86	F1-11
368	S&P	C1-13	0.33	0.49	0.77	0.41	0.62	1.06	F1-04
340	S&P	C3-01	0.02	0.04	0.03	139	298	604	F1-13
340	S&P	C3-02	0.004	0.005	0.01	37.0	50.1	67.8	F1-07
340	S&P	C3-03	0.004	0.008	0.01	0.02	0.03	0.05	F1-06
538	S&P	C4-01	0.04	0.05	0.08	0.04	0.05	0.08	F4-02
538	S&P	C4-02	0.05	0.07	0.11	0.06	0.11	0.19	F1-03

Note: measurements of leak flow rates of small cans before use (called "new" in the table) are done on small cans only. References are given by "C", so C1, C2, C3, C4 corresponding to 4 different brand names and the number after corresponds to the tested can.
Then measurements are done after first use. Results are given in columns "used" and all tests have been carried out with the can connected to a charging kit. For example, C1-01 means that can C1 has been tested after a first use with the charging kit F1-01.

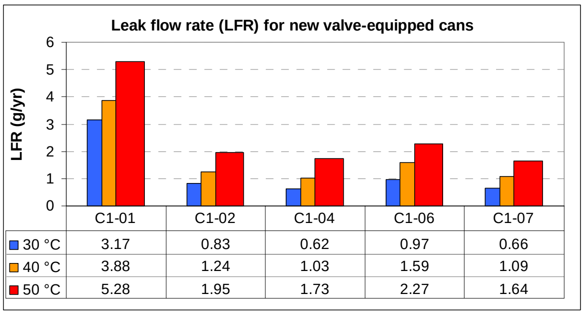
Leak tests on V-type small cans

For the valve-equipped cans (V-type), emissions are always slightly higher compared to S&P ones and in one case significantly higher (3.2 g/yr at 30°C). Values measured before and after can usage are of the same order of magnitude.

All cans are brand new and when the tests are made before use, the test is labeled (BN). Five of the V-type small cans have been tested. These cans are all manufactured by Interdynamics. Since self-closing valve is installed on the can, the charging kit does not contribute to refrigerant emissions before and after a partial use.

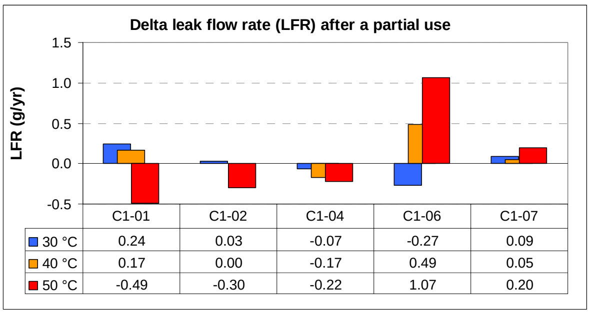
Refrigerant emissions for new valve equipped cans are presented in Figure 4.7. As the leak flow rate and the saturation pressure are related in a quadratic relation, it is obvious that the leak flow rate increases with temperature. Refrigerant emissions from *C1-01* can are three times higher than the other V-type cans and lower than 6 g/yr.

The second series of tests performed after a first use of the five V-type small cans are labeled (AU). As shown in Photo 4.11, the actuator of the self-closing valve only pushes the stem downward and, when released, a spring pushes the stem and closes the container. This means that changes on emissions after use could only be related to the rubber seal that moves with the stem. Figure 4.8 shows that the variation of the leak flow rate after a first use is never higher than 1 g/yr and, in the case of the *C1-01* can, is 0.5 g/yr lower than a new can.



	C1-01	C1-02	C1-04	C1-06	C1-07
30 °C	3.17	0.83	0.62	0.97	0.66
40 °C	3.88	1.24	1.03	1.59	1.09
50 °C	5.28	1.95	1.73	2.27	1.64

Figure 4.7: Leak test results of new V-type cans (BN).



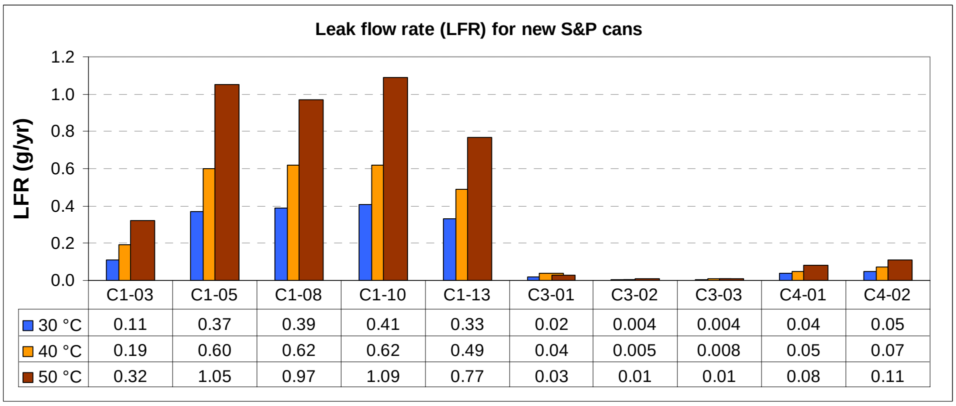
	C1-01	C1-02	C1-04	C1-06	C1-07
30 °C	0.24	0.03	-0.07	-0.27	0.09
40 °C	0.17	0.00	-0.17	0.49	0.05
50 °C	-0.49	-0.30	-0.22	1.07	0.20

Figure 4.8: Leak test results of V-type cans (AU).

Leak tests on S&P type small cans

Five brand new S&P small cans have been tested.

The leak test results for BN S&P small cans illustrate an important difference among the three different manufacturers that have been tested (see Figure 4.9). S&P small cans from manufacturer *C1* are significantly more emissive than *C4* and *C3* ones. For the same container pressure and type, we found refrigerant emissions from *C1* cans, which are 100 times higher than *C3* and *C4* ones.



	C1-03	C1-05	C1-08	C1-10	C1-13	C3-01	C3-02	C3-03	C4-01	C4-02
30 °C	0.11	0.37	0.39	0.41	0.33	0.02	0.004	0.004	0.04	0.05
40 °C	0.19	0.60	0.62	0.62	0.49	0.04	0.005	0.008	0.05	0.07
50 °C	0.32	1.05	0.97	1.09	0.77	0.03	0.01	0.01	0.08	0.11

Figure 4.9: Leak flow rate test results of S&P cans (BN).

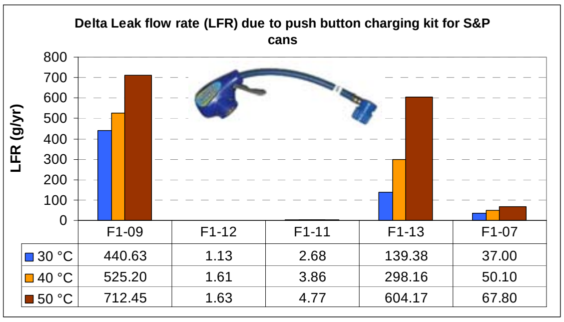
These five S&P cans have been perforated for a first use and re-tested to evaluate the valve technology (see Table 4.2) impact on the refrigerant emissions. These test results are presented in Figures 4.10 and 4.11.

From the test results, it can be concluded that the push button charging kit technology is much more emissive than the shut-off valve. The lowest leak flow rate value obtained for push button valve is about 1 g/yr and the highest one is about 700 g/yr, which proves the leak prone behavior of this technology.

The leak flow rates of S&P cans, after use, depend on the type of charging kit used. The leak flow rate of F1-02 charging kit (dedicated to V cans) is quasi similar to the one of a new S&P can. In contrast, F1-13 charging kit presents very high LFR (139 g/yr at 30°C) and F1-09 also with annual LFR of 441 g/yr. F1-07 is neither satisfactory with 37 g/yr at 30°C. Of course, all charging kits where the refrigerant release is higher than 3 g/yr will lead very quickly to an empty can.

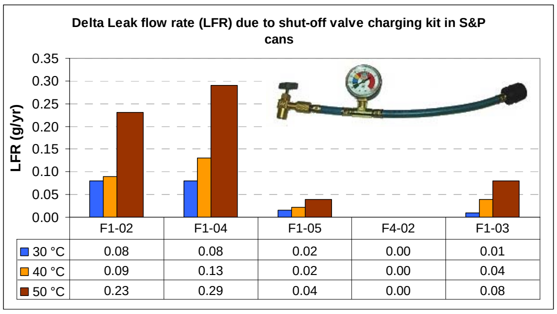
It can be concluded that some charging kits cannot be used on S&P cans after a partial charge, leading to a complete loss of the remaining refrigerant. Moreover, when using F1-13 charging kits, during operation the CEP technician has noticed significant emissions.

When using charging kit *F1-09* at 30°C, the annual leak flow rate exceeds 400 g/yr, meaning that refrigerant container will be empty in a few days. If a user chooses to use a shut-off valve and closes it after the re-charging process, the increase in refrigerant losses could be neglected.



	F1-09	F1-12	F1-11	F1-13	F1-07
30 °C	440.63	1.13	2.68	139.38	37.00
40 °C	525.20	1.61	3.86	298.16	50.10
50 °C	712.45	1.63	4.77	604.17	67.80

Figure 4.10: Test result of the push button charging valve (AU).



	F1-02	F1-04	F1-05	F4-02	F1-03
30 °C	0.08	0.08	0.02	0.00	0.01
40 °C	0.09	0.13	0.02	0.00	0.04
50 °C	0.23	0.29	0.04	0.00	0.08

Figure 4.11: Test result of the shut-off charging valve (AU).

The shut-off valve technology has a very low impact on refrigerant emissions and, for the charging kit *F4-02*, has no impact at all. The high performance of the shut-off valve is related not only to the use of just two seals, but also to the applied load in both seals. One of them is metal-to-metal (see Photo 4.12).

4.2.4 Conclusions

Based on the 90 leak tests presented, refrigerant emissions from small cans before and after a partial use could be important and depend strongly on the container and charging kit technology.

Two different small can technologies have been tested: the V-type and the S&P type. As it could be expected, S&P small cans before use show lower emissions compared to V-type small cans. Particularly the S&P coming from the brand name *C3* shows the lowest emission level, which is nearly nil (see Figures 4.7 and 4.9). This means that, when stored in the sales store, the S&P type small cans leak less than the V-type ones. Nevertheless, the initial level is low for the two technologies.

The charging kits are adapted to the container type. For valve-equipped cans, the charging kit does not modify refrigerant emissions. Therefore, they present almost the same emissions level after a partial use (see Figure 4.8).

Two different charging valves have been tested for S&P type cans. The push button type has a highly irregular emissions behavior and an increase of 712 g/yr has been measured at 50°C (see Figure 4.10). The shut-off valve has been tested in the same conditions and presents emissions lower than 0.3 g/yr (see Figure 4.11). The S&P type cans with a push button charging kit and the valve-equipped cans have a self-closing system that prevents the user to empty the container in a few seconds.

In order to reduce refrigerant emissions before and after re-charging process, appropriate cans and charging kits have to be chosen. These test results suggest the use of S&P cans with a shut-off valve charging kit to minimize HFC-134a emissions.

Recommendations

The LFR study does not indicate any advantage of the V-type can compared to the S&P type. The only emissive component found is the so-called "push-button" charging kit, which has to be either re-designed or banned.

If small cans were still to be used, there is no advantage to use large cans (19 oz.) compared to the smallest ones (12 oz.).

The general overview of servicing is necessary in order to make adequate decisions for servicing either by DIYers or by professionals (see General Conclusions).

4.3 DYE laboratory tests

4.3.1 Introduction

In order to determine the effectiveness of the leak search methods, a first comparative study of leak sensitivity of:

- dye
- electronic leak detectors
- and the soap bubble method

has been carried out, using the infrared spectroscopy to measure exactly which LFR can be detected by each method.

Five fittings with the same design and different LFRs have been chosen (see Photo 4.17). They are composed of two flanges and one o-ring seal, and put together with a screw.

Photo 4.17: Fittings technology used for this comparative study.

4.3.2 Test procedure

First, each fitting has been put under pressure with HFC-134a and installed inside an accumulation volume to be leak tested using an Infrared Spectrophotometer (IS). Refrigerant pressure is set to 770 kPa and the fitting temperature at 35°C, superheated of 5°C to avoid refrigerant condensation inside the component. This leak test is the same as the one described for the small can leak tests. This first test is followed by a leak search using an Electronic Leak Detector (ELD) and a Soap Bubble (SB) test.

The ELD leak detection is achieved by placing the sniffer as close as possible of the component and then moving slowly all around the flanges junction. If the leak detector audible alarm intensifies, then the leak is considered as detected.

The SB leak detection is achieved by spraying the flanges junction with a soap solution. When bubbles formation is visible to the naked eye, then the leak is considered detected.

Before the leak search, the ELD is checked with a calibrated leak of 6 g/yr (see Photo 4.18).

Photo 4.18: Calibrated leak for checking the ELD.

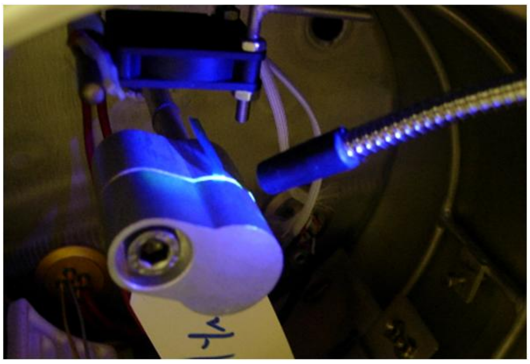


Photo 4.19: Leak detection with ELD.

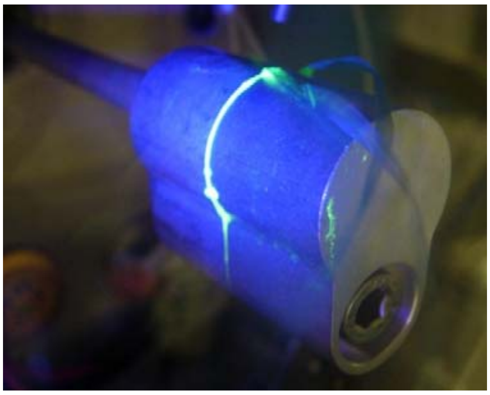


Photo 4.20: Leak detection with DYE

Photo 4.21: Leak detection with soap bubble (1200 g/yr).

The refrigerant LFR measured for samples no.4 to 6 have been performed before the DYE visualization.

Second, without disassembling the flanges, fittings have been charged with refrigerant HFC-134a, PAG lubricating oil and DYE. The refrigerant pressure is set to 770 kPa and the fitting temperature to 35°C. Then, they have been observed with a fluorescent light to determine the time taken by the refrigerant, oil, and dye to go through the leaky seal (see Photo 4.19). Once the test has led to positive detection, the refrigerant LFR is measured with the infrared spectrophotometer. Third, the electronic leak detector and the soap bubble are also tested (see Photos 4.20 and 4.21).

4.3.3 Leak test results

When comparing Tables 4.4 and 4.5, the fittings being in the same conditions, the lubrication effect is very significant, especially for high LFRs. For example, for fitting no. 1, the lubrication of the fitting results in reducing the LFR from 662,000 g/yr to 14.7 g/yr, and for Sample no. 2 from 1,490 to 120. This effect is systematic even if no general law can be derived from those tests. Lubrication of all fittings leads to significant improvement of leak tightness.

For dry contact, only electronic leak detector and soap bubble can be used because dye is diluted in the oil. As it can be seen in Table 4.4, the practical limit of detection has been 7.2 g/yr for both ELD and SB.

Table 4.4: LFRs of fittings with dry contact.

1st leak test - Dry contact			
Test method / Sample	IS [g/yr]	ELD	SB
No.1	662,000	Detected	Detected
No.2	1,490	Detected	Detected
No.3	515	Detected	Detected
No.6	300	Detected	Detected
No.4	7.2	Not detected	Not detected
No.5	0.28	Not detected	Not detected

For the second series of tests with lubricated joints, strangely enough the threshold detection has been different and even a LFR of 14.7 g/yr has not been detected either by ELD or SB, but has been detected by dye.

When comparing Samples 1, 2, and 3, it can be deduced that the lower the LFR, the longer the time for the dye to go through the leaky fitting. Sample no. 3 seems to indicate that a leak as low as 5.7 g/yr can be detected by dye only after 11 hours, this leak not being detected neither by ELB not SB.

Table 4.5: LFRs of fittings with lubricated contact.

2nd leak test - Lubricated contact				
Test method / Sample	IS [g/yr]	ELD	SB	DYE [hr]
No.1	14.7	Not detected	Not detected	3
No.2	120	Detected	Detected**	0.8
No.3	5.7	Not detected	Not detected	11
No.6	0.7	Not detected	Not detected	***
No.4	0.05	Not detected	Not detected	*
No.5	0.05	Not detected	Not detected	*

*No evidence of DYE after 21 days of test
** Very small bubbles
***No evidence of DYE after 15 days of test

After 21-day test, no evidence of DYE has been noticed for samples no.4 and 5.

For sample no.1 (14.7 g/yr with a lubricated contact), the SB method has generated very small bubbles, which were very difficult to visualize.

It has to be noticed that for ELD and SB leak test methods, the leak search strongly depends on the leaky component accessibility. If fittings are not fully accessible, the leak visualization or location can be very hard to find. For the compressor shaft seal, the refrigerating system most leaky seal, detection using ELD and SB methods is impossible because the clutch assembly hides the shaft seal.

In conclusion, adding dye in the oil seems to be a simple and efficient way to detect leaks in the very busy environment of vehicle under hood. Those first tests do not indicate a significant advantage of usual methods (ELD or SB) compared to the use of dye.

The detailed fitting emissions are presented in Appendix 4a.

4.3.4 Conclusions and recommendations

The laboratory tests have not shown significant advantage of usual methods (ELD or SB) compared to the use of dye. These results are shown for the first time and are counter intuitive. Complementary work could be done in order to generalize the capability of dye for different types of leaks coming from fittings or other components.

In real conditions of leak search inside the vehicle under hood, the ELD and SB leak test methods, strongly depends on the accessibility of the leaky component. If fittings are not fully accessible, the leak visualization or location can be very hard to find. For the compressor shaft seal, which is the refrigerating system most leaky component, detection using ELD and SB methods is impossible because the clutch assembly hides the shaft seal.

In conclusion, adding dye in the oil seems to be a simple and efficient way to detect leaks in the very busy environment of vehicle under hood. Including dye in the oil compressor could be done initially at the assembly of a brand new car. Presence of dye neither changes the lubricant properties of oil nor changes the heat exchange capabilities of the refrigerant in the heat exchangers. Adding dye at the beginning of life of the vehicle gives easiness to the leak search whether done by professionals or by DIYers. Small UV lamps are available at costs in the range of 15 US $. For the current fleet, in a number of cases, professionals inject dye with a specific syringe or by using small cans of refrigerant containing also oil and dye. When the fluorescent dye circulates in the refrigerating circuit, there is no need to add dye except if the compressor is changed.

In summary, fluorescent dye is simple and effective way to indicate leaky components and its use should be generalized.

4.4 Conclusions of Section 4

Different tests have been carried out in laboratory conditions. The analysis of small can emissions without charging kit has shown a very low level of emissions. There is no advantage in terms of leak tightness of the V-type compared to the S&P-type before use. After a first use, if a shut-off valve is used on a S&P-type there is no problem of leak compared to the V-type. Many charging kits show a low level of emissions except the push button type, which has to be either redesigned or banned due to its high level of emissions. The study of the charging method with R&R machine has shown rather low level of emissions of quick couplers. Nevertheless some quick couplers are significantly better than others. The automated R&R machine is the essential equipment to limit refrigerant emissions due to its automation and the few connecting operations that are needed. Several studies, carried out by the CEP out of the scope of this study, have shown that the low pressure threshold of the recovery machine has a significant effect on the emissions due to the system evacuation before charge. The recommendation is to change the low pressure threshold, which is usually set around 14 Psia, to 4 Psia.

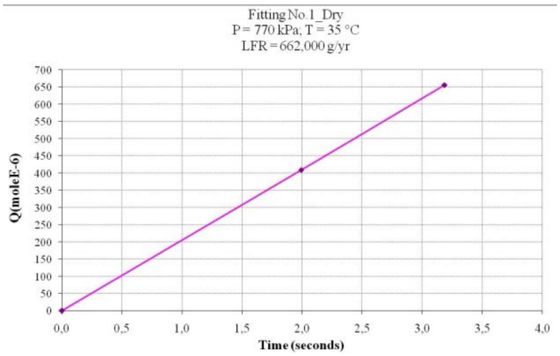
Simulations of continuous refrigerant loss from a MVAC system have shown that no significant temperature change of blown air can be acknowledged before the loss of nearly 50% of the refrigerant charge. A complementary study made for ADEME [TRE06] on ten different MVAC systems has also shown that for nearly all systems, more than 40% of the refrigerant charge has to be emitted before any possible diagnosis of refrigerant loss based on the blown air temperature.

Comparisons of electronic leak detectors, soap bubble method, and leak detection using fluorescent dye and UV lamp have shown that the dye is more sensitive than the other methods providing that sufficient time is elapsed between charging the dye and searching the leaks.

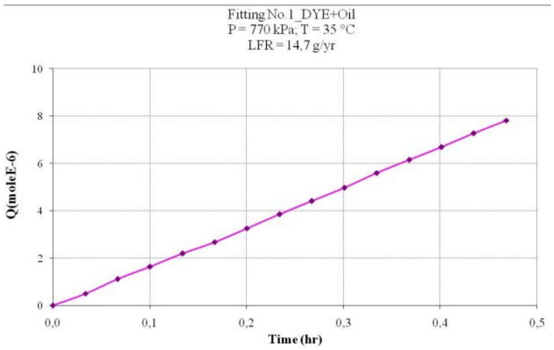
Recommendations

Dye gives easiness for leak search and should be associated with refrigerant charge from the beginning of the vehicle lifetime, meaning that dye could be charge with oil at the vehicle assembly.

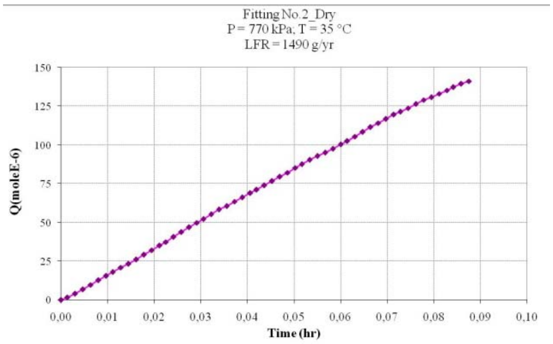
Appendix 4a: detailed fitting emissions



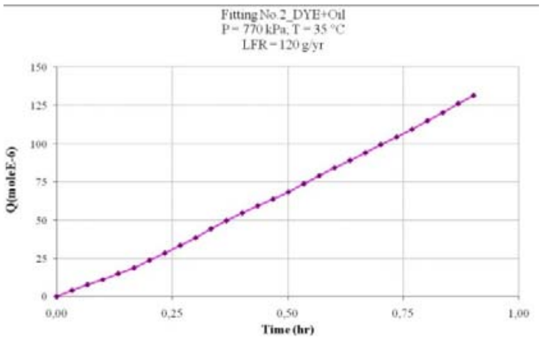
Fitting No.1 : Dry contact



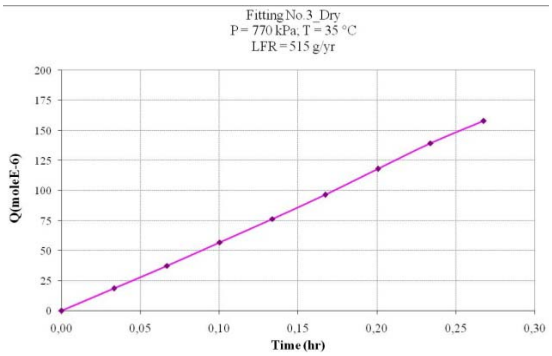
Fitting No.1 : Lubricated contact



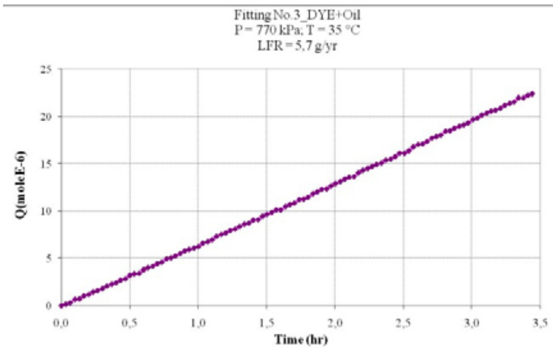
Fitting No.2 : Dry contact



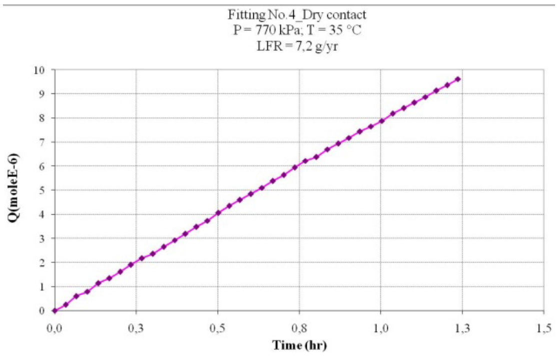
Fitting No.2 : Lubricated contact



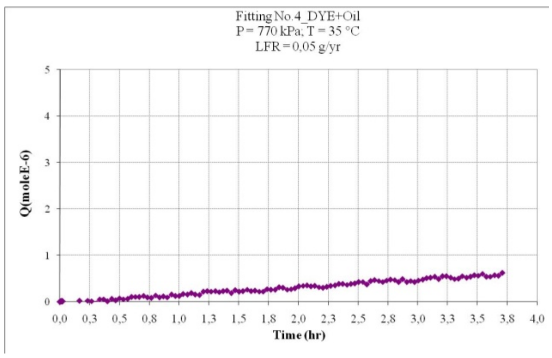
Fitting No.3 : Dry contact



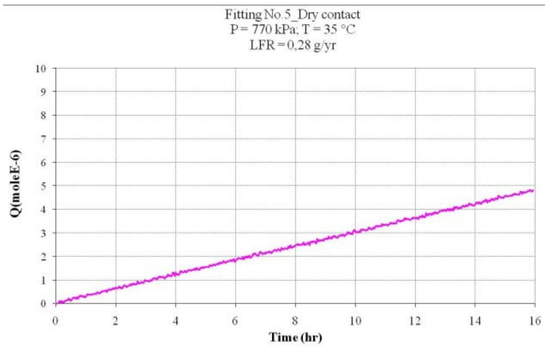
Fitting No.3 : Lubricated contact



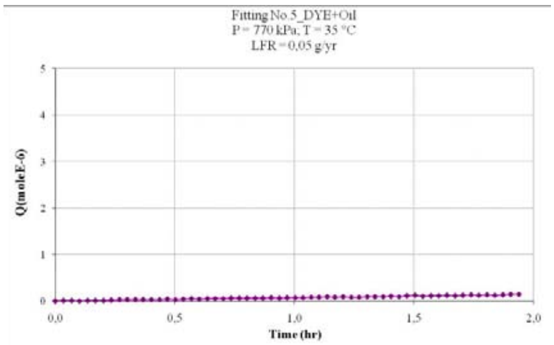
Fitting No.4 : Dry contact



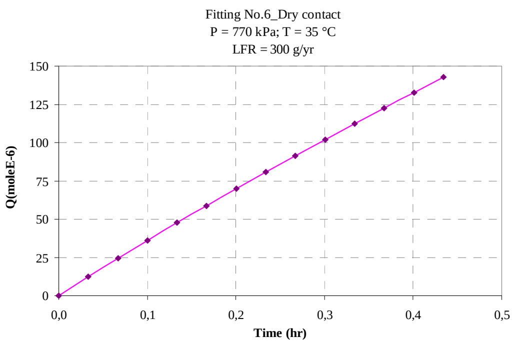
Fitting No.4 : Lubricated contact



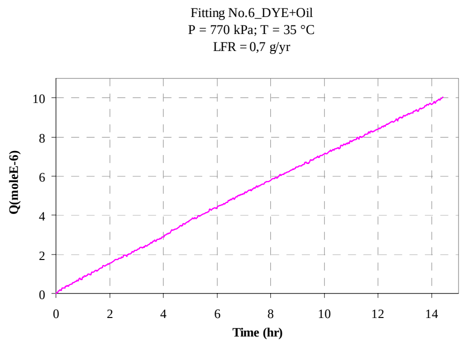
Fitting No.5 : Dry contact



Fitting No.5 : Lubricated contact



Fitting No.6 : Dry contact



Fitting No.6 : Lubricated contact

5. Evaluation of the sales of HFC-134a disposable cans in California

Two sources are available to evaluate the number of small cans sold in California. Based on CARB Consumer Product Survey 2006, the number of HFC-134a small cans sold in California is evaluated to 2 million cans per year equivalent to 0.85 MMT CO_2 equivalent per year. This data have been presented by CARB at the Scottsdale SAE Conference 2008 [ZHA08].

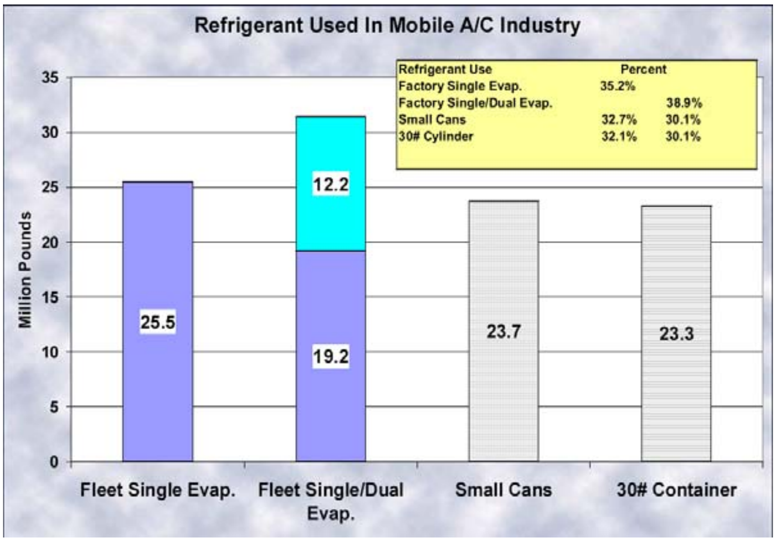


Figure 5.1: HFC refrigerant sales for MVAC systems - 2003 [HOF05].

In 2005, E. Hoffpauir of MVACS has presented the refrigerant sales of HFC-134a for servicing and for new vehicles, as shown in Figure 5.1. So small cans represent 23.7 million of pounds, i.e. 10,750 metric tonnes of R-134a. When taking a GWP of 1300, this represents approximately 1.4 MMT equivalent CO_2.

If we assume that California represents 10% of the U.S. small can sales (which is a usual assumption of the ratio between the Californian market to the US market), the number in equivalent CO_2 is higher, in the range of 1.3 MMT equivalent CO_2.

In any case, the order of magnitude of direct emissions is in the range of 330 MMT equivalent CO_2 per year due to emissions during servicing by DIYers.

Taking into account those two numbers, the sales of R-134a refrigerant contained in small cans in California is

$$0.85 < \text{R134a sales in SC} < 1.3 \text{ MMT equivalent } CO_2$$

From those two series of data, it can be derived that 1 MMT equivalent CO_2 is in the order of magnitude of the R-134a refrigerant sales in small cans from 2005 to 2008. If we consider that 80% of the market of small cans are used by 80% of DIYers and 20% by professionals, emissions associated with DIYers are considered to be 33% of the content of the small cans, which means that 264,000 metric tonnes of equivalent CO_2 are emitted by DIYers.

Assuming that professionals are better trained and that emissions correspond to the experts (see Figure 2.28) met during the survey of DIYers operation, we can consider a refrigerant loss of 1.5% of the small can content, leading to 3,000 metric tonnes of equivalent CO_2. The order of magnitude of annual emission rate of R-134a from small can servicing can be estimated at 267,000 metric tonnes of equivalent CO_2. Of course, we can take an uncertainty of ±20% on these data, which are related to the exact quantity of annual sales as well as variation in the know-how of DIYers and professionals.

6. General conclusions and recommendations

This report has collected new data from two field studies describing operating modes of professional and non professional for servicing MVAC systems. Complementary laboratory studies have established emission levels of MVAC systems used in California as well as emissions from small cans depending on their types and the charging kits to which they are connected. Simulations of operating mode of professionals at the laboratory and previous knowledge of the CEP have led to propose improvement of recovery machines and leak detection methods.

Available data [THA08] indicate that 2 million cans have been sold in 2006 in California. Taking into account emissions as analyzed from the operating mode of DIYers, annual emissions due to servicing by small cans is estimated at 267,000 metric tonnes of equivalent CO_2.

a) Regular leaks of MVAC systems and servicing

The annual LFRs of MVAC systems of the five most sold cars in California have been measured according to the methodology defined in the EU regulation 706/2007 [EUR07]. The initial annual LFRs of those five MVAC systems are of the same order of magnitude as those measured on European or Japanese cars. The average annual LFR of new systems is in the range of **10 g/yr ± 4** and possibly slightly higher for some double evaporator systems.

Tests made on MVAC system test bench running continuously during 7 hours, with a leak in the range of 1.5 g/min., show that about 50% of the refrigerant charge has to be lost before possible diagnosis of insufficient cooling (Section 4.1.1).

Recommendation: No servicing is needed on the refrigerating circuit of MVAC systems during at least the first 7 years (except if no cooling is acknowledged), because the “regular” leaks are low. The servicing documents of new cars should indicate that for the first years the usual way of servicing MVAC systems is NO servicing, except for the change of filters on the air circuit.

Complementary research work is needed to analyze the leak tightness degradation of compressor shaft seals due to several years of operation, in order to understand when MVAC systems become significantly more emissive and require refrigerant recharge.

b) Emissions from small cans (Section 4.2)

Before usage, the 2 types of cans: screw & perforated (S&P) and valve-equipped (V) are not significantly emissive. The leak tightness can be considered good. Different charging kits have been tested for S&P type cans. The kit equipped with the so-called “push button type” is highly emissive (more than 500 g/yr) and emits during operation.

Recommendations: The S&P-type can does generate more emissions compared to the V-type. If small cans were to be banned all have to be.
The push button charging kit requires a new design or has to be banned.

c) Emissions of refrigerant by DIYers when charging MVAC with small cans (Section 2)

For the studied sample of DIYers, 2/3 of the refrigerant have been charged in the MVAC system 1/3 has been emitted.
The main drawbacks associated with non-professional servicing are:

- Recharge without knowledge of remaining refrigerant and of the reference charge
- Recharge without leak search
- Recharge without recovery
- Wrong recommendations written on the can or the pressure gauge of the charging kit

Recommendations

If small cans were to be maintained

- Cancel indication on the level of charge as currently written on the pressure gauge of the charging kits.
- Key indications to be written on the can tag for the charging operation:
    - the engine has to be set ON
    - the MVAC system has to bet set ON and at maximum air flow rate
    - shaking the can for efficient charge of the refrigerant has to be explained
    - the method to diagnose that the can is empty (no noise coming from the liquid when shaking, and temperature raise due to the end of the liquid evaporation).

d) Costs of professional and non professional servicing

For simple recharge without leak search, the cost of recharge is multiplied by a factor 3 to 4 when comparing the cost a small can and the cost of recharge with a small can by a professional (20 $ compared to 80 $). When using a recovery machine with or without leak search the average cost is 120 $.

e) Added values of professional servicing

The possible added values of professional servicing are:

- correct diagnosis of failure
- efficient leak search
- use of R&R machine
- capability of repair.

How the diagnosis has been performed by the sample of professionals?

These first check-ups have included:

- verification of the blown air temperature in the cabin,
- control of the compressor clutch,
- measurement of the low and high pressures (AC on),
- analysis of refrigerant using an electronic analyzer plugged on the service valves,
- verification of the pressure inside the AC loop by pressing the HP or LP valves.

Note: the temperature of blown air in the cabin is done by DiYers as well as professionals; the other ones requires expertise and equipment.

f) Professional servicing and leak search

26 technicians have performed the leak check using 5 methods:

- Controlling the rise of pressure after evacuation (7)
- Direct UV detection (22) including 3 technicians who noticed that the system is already charged with DYE
- Later UV detection (20)
- Electronic detection (14)
- Pressurized air or CO_2 with soap bubble (2).

Except leak search with dye, which can also be done by DIYers using small cans that comprise refrigerant + oil + UV dye, the other methods require expertise and equipment.

For the sample of professionals, none of the leak search with electronic leak detector has been successful (even if one slow leak was existing at the expansion valve), neither with other methods.

The lesson learnt by professional servicing on the necessary time lag between charging the dye and making a possible diagnosis of leak is confirmed by laboratory tests.

g) Professional servicing and R&R

About 2/3 of the professionals have used automated Recovery, evacuation and Recharge machine, which are essential for limiting refrigerant emissions during servicing provided the recovery is performed down to 4 psi abs (see below). Nevertheless, even with automated machines, few professionals verify the original charge of refrigerant required by the car manufacturer.

The most important conclusion is that when professionals use R&R equipment, emissions are drastically reduced, in the range of 20 g per operation providing that the low pressure threshold of the recovery machine is set at 4 Psi abs.

Recommendations

- Systematic leak search before recovery when the saturating pressure is measured within the MVAC system
- Systematic use of R&R machines
- No recharge without verification of the original charge
- Stick a tag in the under hood indicating the recovery and recharge date.

h) Improvement of Recovery and Recharge machines

Some quick couplings are better than others; standard tests should be made to promote the less emissive ones.

Many fully automated recovery machines are making evacuation after recovery and release a significant amount of refrigerant during evacuation due to the threshold of the low pressure low-pressure controller, which stops the recovery process at a pressure around 14 psi abs. This low pressure threshold has to be lowered.

For fully automated machine or for manual recovery machine, the recovered refrigerant has to be precisely weighed after recovery, based on the time elapsed between this recovery and the previous servicing (if any). Knowing the recovered mass, the original charge (tagged on the MVAC system) and the number of months or years, the level of leak can be estimated.

Recommendations

- The low pressure threshold of the recovery machine has to be fixed at 4 psi abs.
- The recovered refrigerant should be weighed and the recovered quantity indicated to the user.
- Each and every servicing operation on a MVAC system should be associated with tag indicating the date and the quantity of refrigerant that has been charged.

i) Leak search and leak sensitivity

Comparison of 3 detection methods (electronic leak detector, soap bubbles, and UV dye) at the CEP laboratory shows that the sensitivity of dye is comparable and even slightly better than the 2 others: capability to detect 6 g/yr after 11 hours.
Even if more sophisticated method could be envisaged, the recommendations in this report focus on what could be easily generalized in order to limit drastically emissions due to MVAC servicing and related actions.

Recommendation

- Dye could be charged with oil initially during the manufacturing process, giving easiness to the leak diagnosis without complementary intervention on MVAC by servicing.
- Small can with refrigerant, oil and dye is a current practice and can be recommended as a search leak method.

j) Servicing MVAC by Do-it-yourselfers without small cans

When comparing the operation mode of a DIYer connecting a small can:

- to the charging kit
- then to the low pressure service valve
- shaking the can with the AC ON for a proper recharge
- feeling that the can is empty

and comparing what has to be done for using an automated R&R machine:

- connection of the blue hose to the low pressure service valve
- connection of the red hose to high pressure service valve
- push the button
- and come back half an hour after

the simplicity is clearly for using an automated machine.

It is possible to discontinue the use of small cans, but still make possible for DIYers to recharge MVAC system by themselves through renting a R&R machine at auto parts dealers. The renting system can be promoted similarly to the one for inflating tires: the end-user does not buy an air compressor to inflate tires of his car.

Providing that UV dye is charged when the car is manufactured, then there is no other constraint for DIYers than renting a UV lamp to the auto part dealer. If UV dye is not charged, it has to be done either by a professional or by using a small can with dye.

Recommendations

If non professional servicing is authorized:

- the operating mode has to be completely changed: no more small cans for recharge but R&R machines to be rented by non professionals at auto parts stores.
- In order to make leak detection possible, UV dye should be charged initially at the manufacturing site and UV lamp to be rented at the auto parts stores
- In the intermediate period, dye either charged by professional or non professional will give easiness to the leak detection process.

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Glossary of terms

AC	Air conditioning
CEP	Center for Energy and Processes
DIYers	Do-It-Yourselfers
ELD	Electronic leak detector
LFR	Leak flow rate
MVAC	Mobile vehicle air conditioning
R&R	Recovery and Recycling and Recharge
S&P	Screw and perforated
SB	Soap bubble
SC	Small can
SCU	Small can user
TXV	Thermo expansion valve

Appendix A (cf. Section 2)

Interdynamics (http://www.id-usa.com/)

S&P and top off cans

Photo	Designation	Fitting type	Capacity / Contents
	AF-3	S&P	13 oz. R-134a 1 oz. of oil, QwikBoost performance booster, leak sealer and O ring conditioners
	AF-6	S&P	19 oz. R-134a
	RFT-134a	S&P	14 oz . 11 oz. of R-134a 2 oz. polyol Ester Oil, o-ring conditioner, Concentrate of “Maxi Cool” Performance Booster with AC Cleaner
	RLS-134X	S&P	13 oz. R-134a Leak Sealer

	RLS-134a	S&P	12 oz. R-134a Leak Sealer
	HMR-134a	S&P	13 oz. R-134a Leak Sealer
	HMT-1DC		7 oz. 6 oz. of R-134a refrigerant 1 oz oil pack of Ester Lubricant and High Mileage anti-wear additives Leak Sealer
	NUV-134a	S&P	13 oz. R-134a AC Fluorescent Dye
	COL-134a	S&P	14 oz. A C Cleaner Leak Sealer O'Ring Conditioner

	ORD-134DC		7 oz. 6 oz. of Refrigerant 1 oz. of Lubricant

Recharging Kits

Photo	Designation	Fitting type	Capacity / Contents
	AF-1	S&P	18 oz. R-134a Oil Leak sealer
	AF-2	S&P	14 oz. 11.5 oz. of R-134a 2.5 oz of oil, QwikBoost performance booster, leak sealer and O ring conditioners
	AFK-11CS	S&P	
	GL-1	Valve equipped	16 oz. R-134a Oil Leak Sealer

	GL-2	Valve equipped	12 oz. R-134a Oil Leak Sealer
	GL-3	Valve equipped	10.25 oz. R-134a Oil Leak Sealer
	GL-11CS	Valve equipped	2 x 12 oz. R-134a Oil Leak Sealer
	BC-1	S&P	22 oz.
	QCK-2CS	S&P	14 oz. 11 oz. of R-134a 2 oz. oil with O-Ring Conditioner and Leak Sealer 1 oz. Xycleen™ auto additives to promote a cleaner system

	MAC-134a	Valve equipped	19 oz. 16 oz. of Refrigerant 3 oz. of Lubricant including Cleaner, Leak Sealer & O-Ring Conditioner
	MAC-134aRFL	Valve equipped	19 oz.
	SD-134a	Valve equipped	14 oz. 12 oz. of R-134a 2 oz. of oil, leak sealer, o-ring conditioner
	RGM-2CS	S&P In Line Gauge	14 oz. 11 oz. of R-134a 2 oz. of Ester Lubricant with O-Ring Conditioner 1 oz. AC Cleaner and Leak Sealer

Combination Retrofit & Recharging Kits

Photo	Designation	Capacity / Contents
	AFK-10	3 cans of Artic Freeze Refrigerant
	RKR-8	3 cans of High Mileage R-134a and Oil Built-in Gauge, adapters and fittings
	RKR-7	Charging hose with pressure gauge in line 3 can of 15 oz. 12 oz. of R-134a 3 oz of oil per can with High Mileage Anit-Wear Additives and "System Safe" Leak Sealer for all rubber leaks
	RKR-5	3 Cans of 15 oz. 12 oz. of Refrigerant 3 oz of Oil
	RKC-3CS	2 Charging Cans of Ester Lubricant 9 oz. of Ester Lubricant O'ring Conditioner 3 oz. of R-134a
	RK-9	•2 oz. R-134a Oil Charge
	BRK-4	PLUS 8-1¼2 oz. of Ester Oil Charge with O-Ring Conditioner for complete system fill. Net Wt. 11 oz.

Charging Kits

Photo	Designation	Fitting type
	MB-134a	S&P
	MB-24EXT	S&P
	HGT-134aCS	S&P
	GBM-2CS	S&P
	GBM-3CS	S&P
	QC-1CS	S&P

JOHNSEN'S

Refrigerant cans

Photo	Designation	Fitting type	Capacity
	R-134a	S&P	12 oz.
	R-134a + UV Glow charge	S&P	12 oz.

Charging Kits

Photo	Designation	Fitting type
	R-134a check & charge hose	S&P
	R-134a Recharge Kit	S&P

QUEST

Refrigerant cans and charging kit

Photo	Designation	Fitting type	Capacity / Contents	Price
	QUEST R-134a with Sub-Zero	S&P	19 oz. 17 oz. of R-134a 2 oz. of Sub-Zero Synthetic A/C Booster, Patented Reusable	$ 91
	QUEST R-134a	S&P	12 oz. R-134a	
	QUEST Quick cool R-134a	S&P	14 oz. 12 oz. of R-134a 2 oz. of PAG Oil to Lubricate and Quite Noisy Compressors, Stop Leak and O-Ring Conditioner	$ 14.68
	QUEST Stop leak	S&P	12 oz.	

	QUEST R-134a Hight Mileage	S&P	13 oz. 12 oz. of R-134a 1 oz. of High Mileage Lubricant	$ 10.97
	QUEST R-134a Sub-Zero	S&P	15 oz. 13 oz. of R-134a 2 oz. of Sub-Zero Synthetic A/C Booster	$ 16.78
	QUEST Sub Zero synthetic A/C booster	S&P	4 oz.	$ 4.79
	QUEST R-134a HIGH MILEAGE	S&P	4 oz.	$ 4
	QUEST R12/R22 Super Seal	S&P	R12-R22	$ 19.99
	QUEST R-134a Cool Down	S&P	Contains PAG oil, R-134a refrigerant, conditioners and sealers	$ 2.66

	QUEST R-134a quick cool			$ 9.70
	QUEST R-134a Oil Charge	S&P	11.5 oz. 8.5 oz. of PAG oil 3 oz. of R-134a plus conditioners	$ 5.32
	QUEST R-134a plus	S&P		$ 8.35
	QUEST R-134a refrigerant with Stop Leak	S&P	12.3 oz.	$ 6.74
	QUEST R-134a Super Seal	S&P		$19.99
	QUEST R-134a Total Treatment	S&P	5 oz. 2 oz. of R-134a, 2 oz. of PAG oil and quite noisy compressors, 1 oz. of Cool Down	$ 3.67

Combination Retrofit & Recharging Kits

Photo	Designation	Fitting type	Capacity / Contents
	QUEST ReChill Kit	S&P	2 x18 oz. of R-134a 4 Oz of Sub-Zero Synthetic A/C Booster

Charging hoses

Photo	Designation	Price
	R-134a recharge hose with gauge handle	$ 14.68
	Manifold gauge & hose set	$ 52.48

Appendix B (cf. Section 2)

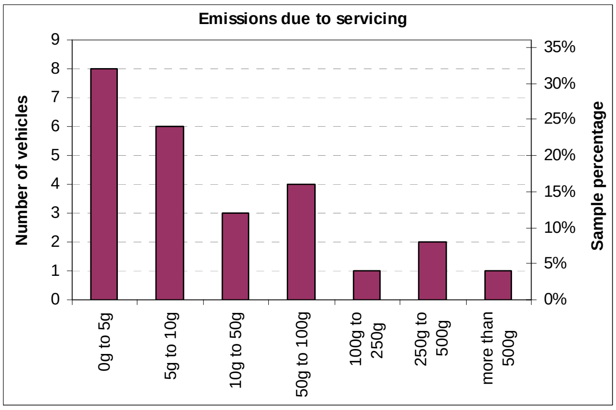

Figure A.1: Number of vehicles as a function of emission range due to servicing (sample 1).

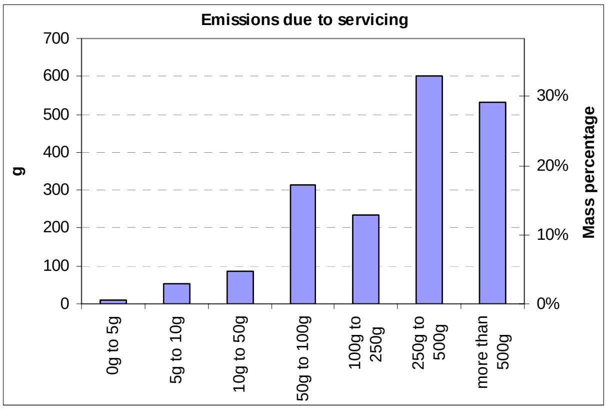

Figure A.2: Mass emission as a function of emission range due to servicing (sample 1).

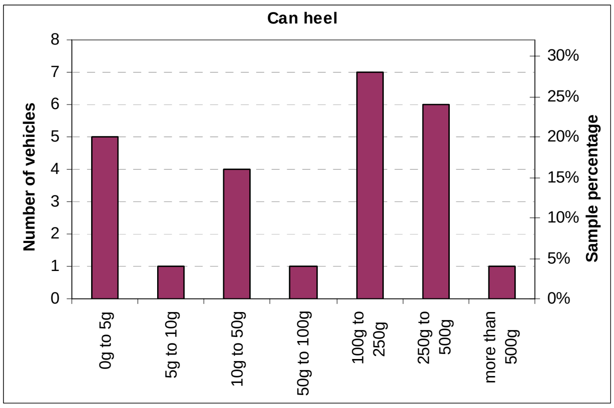

Figure A.3: Number of vehicles as a function of can heel range (sample 1).

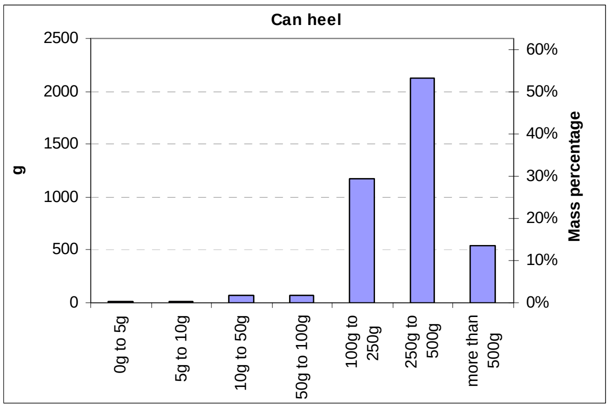

Figure A.4: Mass emission as a function of can heel range (sample 1).

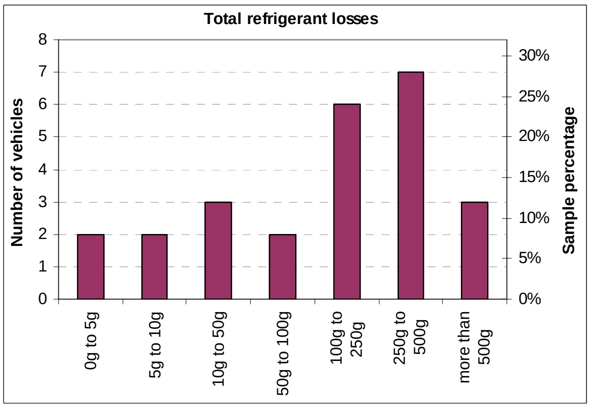

Figure A.5: Number of vehicles as a function of total refrigerant emissions (sample 1).

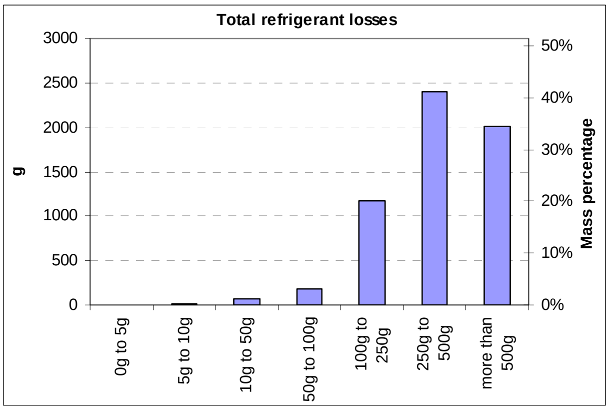

Figure A.6: Mass emission as a function of total refrigerant emissions (sample 1).

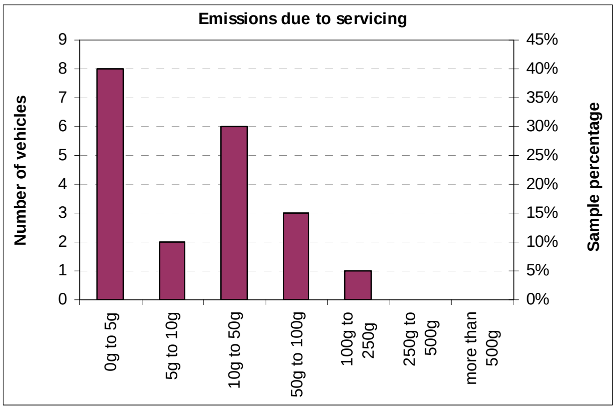

Figure A.7: Number of vehicles as a function of emission range due to servicing (sample 2).

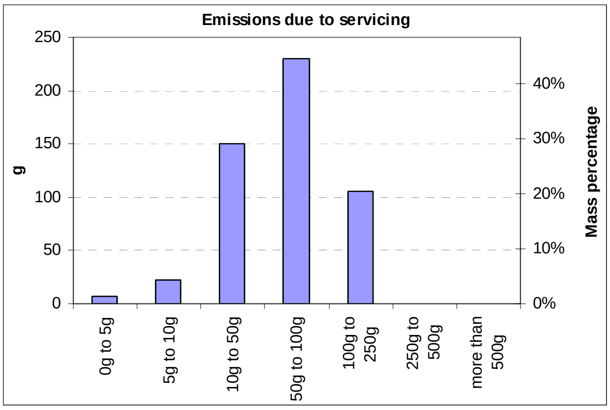

Figure A.8: Mass emission as a function of emission range due to servicing (sample 2).

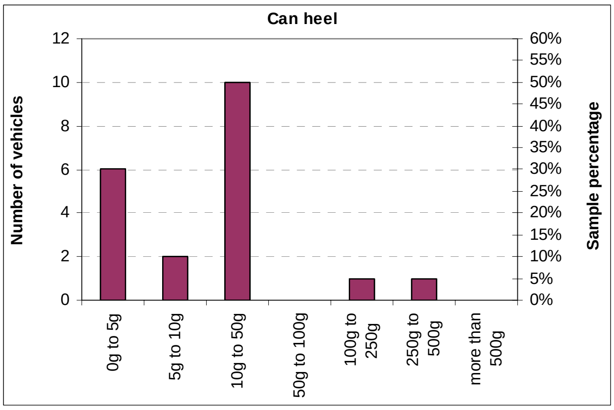

Figure A.9: Number of vehicles as a function of can heel range (sample 2).

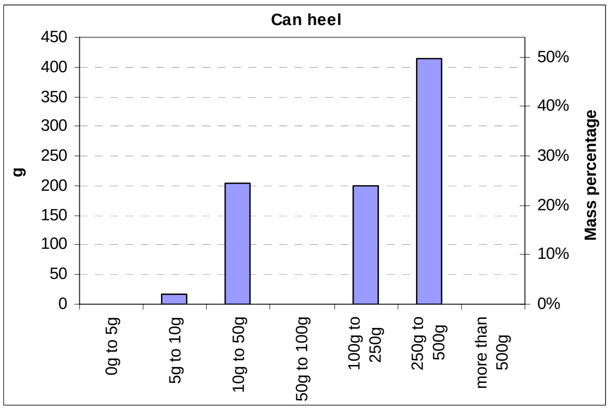

Figure A.10: Mass emission as a function of can heel range (sample 2).

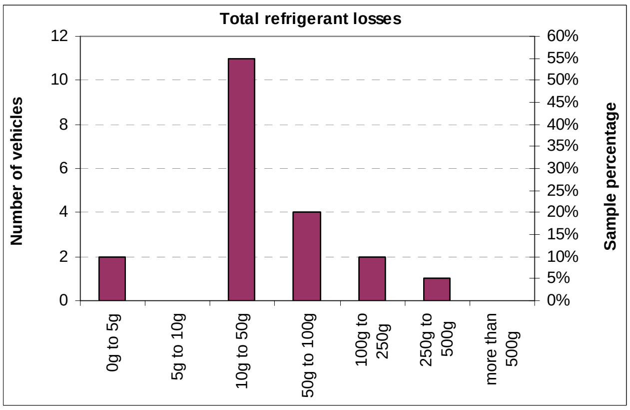

Figure A.11: Number of vehicles as a function of total refrigerant emissions (sample 2).

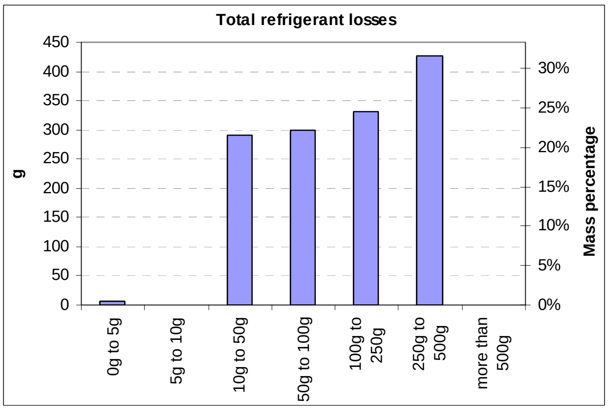

Figure A.12: Mass emission as a function of total refrigerant emissions (sample 2).

Appendix C (cf. Section 3)

Details of garage visits and operations

Garage number: 1 ***Date:*** 09/13/07 ***Vehicle*****:** CADILLAC Deville, retrofitted to R-134a

Two refrigerant leaks have been detected by ARMINES on the MAC circuit (using an electronic leak detector): one on the suction fitting of the compressor and one on the low-pressure service valve (LPSV).

Operation description

First, the technician requests general information such as:
- What refrigerant?
- When has the MAC system been retrofitted?
- Does the system blow cold air?
- What is the car vintage?

Then the same technician looks at the vehicle to check the retrofitting sticker, the mileage of the vehicle. He checks the ventilation, the temperature of the air blown, and the compressor clutch. The manager advises to perform a diagnosis based on a leak search. The quotation for the diagnosis is 19.99$.

Having agreed on the proposed service, a technician is in charge of the vehicle. A gas analyzer is connected to the LPSV of the circuit to verify the refrigerant type. The analyzer indicates 100% R-134a, 0% air.
A rapid tour of the MAC circuit is done with a current lamp to check the various fittings and the condenser.
Then, he turns ON the starter of the vehicle to check the compressor clutch engagement.
An automated Refrigerant recovery and recycling (RRR) group is connected to the high and low-pressure service valves (PSVs). He starts the car, turns on the air conditioning system (maximum ventilation) and the HP and LP pressure levels.
The engine and the air-conditioning being turned off, the automated RRR group is started. The refrigerant is recovered, recycled, and the system evacuated. The refrigerant circuit is maintained evacuated during 15 to 20 minutes in order to verify if the pressure in the circuit goes up. I have not been able to see the pressure value, and thus to know if it increased.
Then oil and DYE have been added, and the MAC circuit has been recharged.

Once the system has been recharged, the system is maintained under pressure during about 30 minutes (engine and air conditioning on for about 15 minutes). After that a leak search is performed, all along the circuit, using an UV lamp and glasses. A leak is found on the LP fitting of the compressor. A second leak search is performed with an electronic leak detector, which confirms the leak on the same site.
The advice is to change the compressor, the suction line, and the liquid receiver. The quotation is of 1,360 $.
We request if only the O-ring at the compressor suction port could be changed. From his point of view, the answer is no, the three components have to be changed.
We argue that the repair cost is too high and ask if the circuit can be recharged without the leaks being repaired. He refuses and we take the car back as is.
The MAC system has been recharged with about 900 g of refrigerant. After the leak search the technician has not recovered the refrigerant.

Prior giving the car back to us, he handed us a complete document on the "recommended service not authorized by customer", and we will notice later that the technician had added a sticker showing the refrigerant type, the refrigerant charge, the name of the garage and OF the operator.

Operation cost: 19.99 $

Garage number: 2 ***Date:*** 09/13/07 ***Vehicle*:** CADILLAC Deville, retrofitted to R-134a

ARMINES has detected two refrigerant leaks on the MAC system circuit using an electronic leak detector: one on the suction fitting of the compressor and one on the LPSV.

Operation description

This garage includes about 4 technicians.

The operator starts the vehicle and the air conditioning system.

The ventilation is set on the maximum to check the blowing and the temperature of the blowing air. He also checks that the compressor clutch engages properly. He notices the retrofitting labeling we had previously posted.

The operator connects a manifold on the HP and LP service valves (SVs) in order to check the service pressure of the system. He notices that the compressor cycles and the LP oscillates.

He diagnoses that the refrigerant level in the circuit is low and that a leak possibly exists. Then he explains to us how to perform a leak search using UV, but for him the leak is too small and that it will be difficult to identify the site.

He indicates the price for the refrigerant recharge only, and he repeats several times that he does not guarantee that the air conditioning will run over the time. He will also mention that the compressor seems "weak" and proposes to change it. The quotation for that is of 850 $.

We accept the refrigerant recharge. He verifies the manufacturer charge indicated on the label on the under hood and takes two 12-oz small cans (S&P type) with a charging kit.

The operator connects the flexible to the charging kit. He connects the whole to the LP port of the circuit. The first can is screw and perforated (S&P type). He turns on the engine and the air conditioning, and starts the charge with liquid refrigerant (can upside down).

He has the feeling that the can is empty. He opens the clamp to deliver the can and S&P the second one. Doing the same, he charges the refrigerant, cylinder upside down. When he thinks that the can is empty, he opens the clamp to disconnect the can.

The small cans contain neither oil nor DYE.

The operator verifies the air temperature at the exit of the blowing outlets and touches several times the suction hose of the compressor.

No leak search is performed.

Operation cost: 80.00 $

Garage number: 3 ***Date:*** 12/12/07 ***Vehicle*: ** Mitsubishi Montero

Operation description

About 10 technicians work in this garage.

The operator recommends me a refrigerant recharge of the air conditioning system and to perform a leak search.

Prior to start the work, he explains to me how he is going to proceed, in particular that he will recharge the system with DYE to locate the leak.

He connects the automated RRR group to the HP and LP SVs, checks the pressures with the A/C off, and then with the A/C on.

He inspects the circuit with a classical lamp. No specific default is found.

The engine being off, he starts the RRR group. He recovers and recycles the refrigerant. He evacuates the system and recharges the nominal charge of refrigerant with an addition of DYE (the operator has verified the charge on the label existing on the under hood). The duration of the operation is of about 45 minutes.

Once the recharge is done, he disconnects the valves from the HP and LP ports and checks the circuit with an UV lamp.

He tightens the Schrader of the HP port. Incidentally, he pushes twice the Schrader and some gas is released to the atmosphere.

Then he checks the circuit with an electronic leak detector. No leak is found.

The operation ends by a test on the operation of the MAC system. The vehicle is started and the A/C is also started at high speed (maximum ventilation with recycled air). He checks the temperature of blown air.

Operation cost: 104.24 $

Garage number: 4 ***Date:*** 12/13/07 ***Vehicle*:** Mitsubishi Montero

Operation description

There are about 7 technicians in the garage.

The operator recommends a complete diagnosis (19.99 $).

The operator checks the blowing temperature and the ventilation inside the cabin. He checks visually the compressor clutch.

He connects the automated RRR equipment to the HP and LP SVs and checks the pressure levels.

After those first verifications, he recovers the refrigerant, evacuates the system, adds some DYE, and recharges the circuit. I do not know whether the circuit is recharged to the nominal charge or only with partial charge.

Then, he performs a leak search with an UV lamp and specific eyeglasses. All the circuit is checked and the evaporator is thoroughly checked. The diagnosis of the operator is as follows:
Low refrigerant pressure, overfilled with oil (probably can refill). The system needs to be evacuated and recharged with 1.5 lb R-134a. No UV leak detected.

The operator recommends repairing the system by recovering the refrigerant and recharging the circuit. He gives me a list of recommendations to repair the system. The quotation for this operation is 177.42 $. I refused the repairs.

The technician has lost the cap of the LP SV. He replaced it by another one that does not fit.

Based on the remarks of the operator, I dismount the complete suction line of the compressor and the fitting of the liquid line to check the oil in the circuit. Hoses are not filled up with oil. Nothing is abnormal.

Using the vacuum pump, I evacuate the circuit. I add some R-134a, and again I evacuate the circuit using the transfer group down to 30 kPa. Then I charge about 150 g of refrigerant. I perform a leak search with an electronic detector on the fittings I have just disassembled. The fitting of the compressor suction is OK. There is a small leak on the fitting of the evaporator outlet on the expansion valve.

Operation cost: 19.99 $

Garage number: 5 ***Date:*** 12/14/07 ***Vehicle*:** Mitsubishi Montero

Operation description

The garage is small, only one operator.

The operator starts the vehicle and the A/C system. He checks that the AC system blows cold air. Then he looks at the compressor clutch to verify the engagement. He connects a manifold and checks the HP and LP SVs of the circuit.

His diagnosis is that there is not enough refrigerant. He says that there may be a leak somewhere. I ask if the leak can be fixed or if the system can be recharged. He answers that the leak is too small to be located and recommends going ahead with the recharge. He insisted on the fact that he will not guarantee the service.

The operator checks the charge indicated on the label. Then he goes at the back of the garage to pick up two small cans (12 oz) and one connecting kit. The kit is already connected to one small can. He unscrews it and the can leaks significantly (liquid and gas). He connects the kit to one of the two new small cans and connects the whole to the LP SV. He turns on the car and the A/C system. He fills up the refrigerant in liquid phase. He does the same with the second small can.

During the charge, he puts a hand on the suction line of the compressor and checks several times the air temperature at the blowing outlets.

Cost operation: 70.00 $

Garage number: 6 ***Date:*** 12/15/07 ***Vehicle*:** Mitsubishi Montero

Operation description

The garage is small and includes one main technician and one operator.

The operator opens the under hood and press several times (at least 5) the Schrader of the LP SV. Each time refrigerant is released.

The technician joins us and asks me to start the car and the A/C system with the maximum ventilation speed. He checks visually the compressor clutch engagement. He takes the screw driver and presses again 3 or 4 times on the Schrader of the LP SV.

He turns off the car engine. Again he presses several times the Schrader of the LP SV.

Then he offers to recharge the system, but insists that he does not guarantee the operation. I agree to his offer.

He picks up a 12 oz small can and a charging kit equipped with a pressure gauge.

He charges liquid refrigerant. No refrigerant release occurs during the charge.

He does not make any recommendations and does not perform any leak search.

Cost operation: 60.00 $

Garage number: 7 **_Date:_** 12/16/07 **_Vehicle_**: Mitsubishi Montero

Operation description

This garage is part of a chain of garages offering quick servicing (engine oil, filter, …). He also offer A/C system servicing. I notice that he is also equipped with an automatic refrigerant recovery group.

The garage includes 4 to 5 employees.

The operator enquires about the problem (no cooling). He checks neither the temperature of the blowing air nor the engagement of the compressor clutch.

He only recommends refrigerant recharge. The price for the refrigerant recharge is a lump sum of 130 $. I ask if that price includes a leak search. He answers that they never do that. He says that the price covers a simple refrigerant recharge (recovery + recycling + evacuation, and recharge).

I indicate to the operator that the price is high compared to the service (only recharge). He recommends me to go to Kragen and buy small cans.

Operation cost: NONE

Garage number: 8 **_Date:_** 12/16/07 **_Vehicle_**: Mitsubishi Montero

Operation description

The garage is a medium-size shop including about 4 technicians.

One of them enquires about the problem. He recommends directly refrigerant recharge and leak search using DYE.

The price list offers diagnosis (blowing air, compressor clutch) and leak search for 89 $. Once the diagnosis is done, if nothing is detected, they propose refrigerant recharge for 145 $.

I notice that the garage is equipped with an automated RRR group.

Operation cost: NONE

Garage number: 9 ***Date:*** 12/16/07 ***Vehicle*:** Mitsubishi Montero

Operation description

There are only two technicians in this garage.

The operator checks the temperature and the air blowing in the cabin. He presses twice on the valve of the LP SV. He also checks visually the compressor clutch engagement.

His diagnosis is that the refrigerant level is low. He recommends a leak search and refrigerant recharge.

When doing the leak search, he leaves the circuit under pressure and connects a hose of compressed air to the LP SV. He starts to fill with air and realizes that the Schrader of the LP SV leaks. He recommends replacing it. He does not have a new part and cannot order it. He suggests that I go to a store to buy one and to come back for the refrigerant recharge.

No fee is charged for this diagnosis. I have obtained air in the circuit for free !

I do not come back to the garage because I did not find the part in a specialized store or in another garage.

Operation cost: NONE

Garage number: 10 ***Date:*** 12/16/07 ***Vehicle*:** Mitsubishi Montero

Operation description

I come back in a garage of the chain I have already visited in order to check if all garages offer the same operation mode.

The person in charge tells me the price of a refrigerant recharge: 130 $ without any other information.

I agree.

The operator checks the air blowing and the air temperature at the blowing outlets. He looks at the compressor clutch engagement.

He connects an automated RRR group and looks at HP and LP pressures, with the system ON and OFF.

He recovers and recycles the refrigerant, then evacuates the system, and recharge the circuit with the manufacturer nominal charge that he has read on the label in the under hood.

No DYE is added. I have not been able to see whether or not oil has been added.

No leak search is performed.

He checks that the system provided cooling by measuring the temperature of the air blown in the cabin, prior to give me the car back.

No comment is made on the leak tightness of the system.

Operation cost: 132.91 $

Garage number: 11 _Date:_ 03/03/08 _Vehicle_: Mitsubishi Montero

The vehicle has not been used for three months. A leak search is performed on the A/C system with an electronic detector. No leak is found.

Operation description

The garage is a small one with only one technician. The garage is located in a gas station equipped with two hydraulic car lifts.

I tell him that the A/C system does not cool the cabin. He recommends refrigerant charge. He does not say a word about leak search.

I react as someone who does not understand. He gives me some more details: he uses small cans, 12-oz type with charging kit without pressure gauge. The service cost is 70 $.

I do not make the operation in this garage because he has no time to do it.

Operation cost: NONE

Garage number: 12 _Date:_ 03/03/08 _Vehicle_: Mitsubishi Montero

Operation description

The garage is a medium size one (4 technicians) specialized in radiators and A/C systems.

The technician checks the temperature of the blown air and the engagement of the compressor clutch.

He connects an automated RRR group to the HP and LP SVs, and check service pressures.

After this diagnosis, he recommends leak search before charging refrigerant.

He recovers and recycles the refrigerant, evacuates the system, and recharges it according to the manufacturer nominal charge indicated on the label available on the under hood. The RRR group adds automatically DYE when the circuit is evacuated.

Once the charge is completed, a leak search is performed first with an UV lamp, then with an electronic detector. The leak search duration is about 15 minutes. No leak is found. He recommends me to stop by in about a week to check UV traces.

Operation cost: 138.18 $

Garage number: 13 **_Date:_** 03/03/08 **_Vehicle_**: Mitsubishi Montero

Operation description

This is a small garage with two technicians.

One technician checks the compressor clutch and the temperature of the blown air. Then he connects a manifold and checks the service pressures. He recommends a leak search.

The A/C circuit is under pressure and performs a leak search with an UV lamp during about 2 minutes without even knowing if there is refrigerant in the A/C system. He says that no leak exists.

He says that it is normal; one recharge is necessary every 5 years.

I agree for the refrigerant recharge.

The refrigerant is not recovered and the circuit is not evacuated. He reads the manufacturer charge. He adds liquid refrigerant using the manifold from one cylinder of virgin refrigerant. He uses also a scale to measure the quantity of refrigerant he is charging.

Operation cost: 70.00 $

Garage number: 14 **_Date:_** 03/04/08 **_Vehicle_**: Mitsubishi Montero

Operation description

This medium-size garage includes 2 to 3 technicians.

The garage is specialized in AC systems, short repair, and electric systems.

The operator checks the ventilation and temperature of blown air. Then he checks the compressor clutch and connects a manifold in order to check the service pressures.

He recommends recharge of refrigerant with some DYE. According to him, the leak cannot be located immediately. He also recommends coming back in a few days to check the circuit tightness with an UV lamp.

The operator has processed as follows:

The circuit is under pressure; the initial refrigerant charge is of 102 g.
First, he charges DYE using a pump.
Then he connects a manifold to the HP and LP SVs. The valves of the manifold are opened (gas is released to the atmosphere for about 1 minute).
He puts the refrigerant cylinder upside down and starts the charge in liquid phase.
The A/C system if ON, the manifold valves are wide opened for several minutes.

I have recovered 494 g.

Operation cost: 95.00 $

Garage number: 15 ***Date:*** 03/04/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

Two technicians work in the garage. The garage is specialized in the repair of A/C systems and engine cooling radiators.

The operator checks the ventilation and the temperature of the blown air. Then he checks the engagement of the compressor clutch. The diagnosis is a need of refrigerant. The operator recommends refrigerant charge with DYE to check the leak tightness of the system.

The operator uses an automated RRR group and operates in a usual way: recovery and recycling of the refrigerant, evacuation of the system, and recharge.

Once the system is recharged, the leak check is performed using an electronic leak detector. The operator also opens the small door inside the cabin, on the passenger side, allowing the access to the evaporator. No leak is found. Thus he recommends me coming back after a few days to check if there are DYE traces.

Operation cost: 93.97 $

Garage number: 16 ***Date:*** 03/04/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

The garage is large including more than 8 technicians and the same number of hydraulic car lifts. I am the only one customer in the afternoon.

The garage is specialized in diagnosis and repair of A/C systems.

The first offer is to check the A/C system for a diagnosis (29.99 $). I agree on that.

I am not allowed to enter the working area. I observe the operation from a certain distance.

In a first step, the operator checks rapidly the temperature and the air blowing in the cabin. Then he connects the A/C system to an automated RRR group. I do not know if he adds refrigerant or if the circuit is maintained under pressure. Anyway he performs a leak search using an electronic leak detector (with adjustable sensitivity).

After about 40 minutes of leak search, the operator comes back to me. He explains that no leak has been found. He recommends recovery and recycling of the refrigerant, system evacuation and refrigerant recharge. The quotation is in the range of 100 $, including diagnosis.

I agree.

The operator starts the automated RRR group and program the recovery, evacuation, and refrigerant recharge based on the manufacturer nominal charge that he has read on the system label.

Operation cost: 98.26 $

Garage number: 17 **_Date:_** 03/05/08 **_Vehicle_**: Mitsubishi Montero

Operation description

The garage is specialized in cooling radiators and A/C systems. There are about 5 to 7 technicians.

The operator recommends at once performing a leak search (60 $). He checks the compressor clutch. He connects the automated RRR group (HP and LP SVs) and starts the A/C system.

The LP decreases and the compressor cycles. He stops the car engine. HP and LP are balanced. He takes a usual lamp and has a first look at the system. Then he takes an electronic leak detector and goes all over the system. After several minutes of examination, no leak is found.

He says to me that it might be the condenser or hoses and estimates to 550 $ the repair costs.

I do not agree to the repair. He offers to recharge the system with « stop leak », one small can QUEST (R-134a + oil + stop leak additive). He connects the can to the LP SV. He starts the car engine and the A/C system. He continues the refrigerant charge with the can upside down (in liquid phase) and with a stirring movement.

Operation cost: 119.54 $

Garage number: 18 **_Date:_** 03/05/08 **_Vehicle_**: Mitsubishi Montero

Operation description

The garage is very small, a single operator. He offers a first diagnosis.

He connects a manifold to the HP and LP SVs. He notices that the system is under pressure.

He asks me to start the engine and to turn on the A/C system. The LP drops. He explains that there is not enough refrigerant in the A/C system.

He offers refrigerant recharge for 70 $.

He also says that there may be a leak, and that he does not guarantee that it will work for long.

Thus I request that he performs a leak search in order to locate the leak and repair it. But he tells me that the leak is too small.

He recharges the system, in liquid phase, via the LP SV, the engine and the A/C system both running.

He does not mention DYE.

Operation cost: 70.00 $

Garage number: 19 _Date:_ 03/05/08 _Vehicle_: Mitsubishi Montero

Operation description

The garage is small with only one technician. As usual, I tell him that the A/C system does not work well, no cooling and efficiency has decreased with time.

He says that there may be a leak on the circuit and offers refrigerant recharge with DYE. He recommends to use the A/C system as usual and to come back when the efficiency will be low in order to check the leaks with DYE.

The garage is equipped with an RRR automated group. He recovers and recycles the refrigerant, evacuates the system, and recharges the refrigerant with DYE.

I recovered 699 g.

Operation cost: 94.12 $.

Garage number: 20 _Date:_ 03/05/08 _Vehicle_: Mitsubishi Montero

Operation description

The garage is small with two technicians.

He advertises his services for A/C system checking.

He recommends refrigerant recharge. After I have explained the problem, he connects directly an automated RRR group (only to the LP SV of the system). He does not check the compressor clutch. He notices that the LP pressure cycles, but that the system is under pressure. He reads the manufacturer charge.

He does not recover the refrigerant remaining in the system; he only tops up the charge.

I have recovered 946 g instead of 680 g.

Operation cost: 60.00 $.

Garage number: 21 _Date:_ 03/05/08 _Vehicle_: Mitsubishi Montero

Operation description

The garage is small with two technicians. As most of garages, he advertises A/C servicing.

The operator neither checks the blowing air temperature inside the cabin nor the compressor clutch. He connects directly an automated RRR group (SPX Robinair Cooltech 700) to the HP and LP SVs.

He stars the refrigerant recovery, evacuates the system, and recharges. He has read the manufacturer charge before charging the system. He adds oil and DYE in the system using the RRR group.

Although I insisted, he did not perform leak search. He just tells me to come back later for an overall check of the system.

Operation cost: 89.90 $

Garage number: 22 ***Date:*** 03/06/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

The garage is small with two technicians.

First the operator pushes the Schrader of the LP SV. Result: Pschittt !!!! He feels better: there is still some refrigerant. He also checks the air temperature at the blowing outlets and the engagement of the compressor clutch.

Then he connects an automated RRR group to the HP and LP SVs. He starts the car engine. The LP drops, the HP is low, the compressor cycles…

Diagnosis: compressor or expansion valve problem. The two parts have to be replaced. Estimate of the two parts: 550.00 $.
Estimate of the repair duration: 24 hours.

Diagnosis: FREE

Garage number: 23 ***Date:*** 03/06/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

In this small garage only one technician. He is rather meticulous and performs a thorough operation. He checks the compressor clutch, the air temperature at the blowing outlets, HP and LP pressures (system ON and OFF), and he analyses the gas type in the circuit (3.5% air).

Then he stars the automated RRR group with: refrigerant recovery, system evacuation, and refrigerant recharge.

After the system evacuation, he performs the test of pressure raise in the circuit during 20 minutes (this is an option on the automated group). Result: no pressure raise.

After the refrigerant recharge, he checks the circuit with an electronic leak detector. He inspects all the circuit. He also checks the evaporator leaks through the blowing outlets. Result: no leaks.

When charging the refrigerant with the automated group, he has also added DYE. He recommends me to stop in a garage to locate the leak.

I recovered 591 g of refrigerant.

Operation cost: 120 $ for the full process.

Garage number: 24 ***Date:*** 03/06/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

The garage includes three technicians.

The first thing the operator does is to push the Schrader of the LP SV to make sure that there is gas in the system. Then he checks the air temperature in the cabin, HP and LP pressures, and the compressor clutch. He leaves the system under pressure. Although I insist, he does not perform leak search.

He only tops up the refrigerant charge, engine OFF, using an automated RRR group connected to the HP SV of the system.

Operation cost: 80.00 $

Garage number: 25 _Date:_ 03/07/08 _Vehicle_: Mitsubishi Montero

Operation description

This one is a gas station including a garage. There are two technicians.

Firs the operator checks the engagement of the compressor clutch. He checks the air temperature of the blown air with a thermometer, and touches the hose exiting the evaporator.

He unscrews the HP and LP covers and notices DYE traces. With assurance, he says that the leak comes from that point.

He offers to recover the refrigerant remaining in the system in order to change the Schrader. I question him to know if some other leaks may exist. He answers that the sole source of leaks is the Schrader.

He connects the automated RRR group (Cornwell Tools RAC341342K) to the HP and LP SVs. He recovers the refrigerant in the system. He disconnects the automated group, and replaces the HP Schrader. Then he evacuates the system and recharge refrigerant.

Operation cost: 150.00 $

Garage number: 26 _Date:_ 03/07/08 _Vehicle_: Mitsubishi Montero

Operation description

This medium-size garage includes 5 technicians.

The operator offers to perform leak search for 35 $.

The operator starts the car engine and checks the temperature of air blown.

He connects the automated RRR group to HP and LP SVs and checks if the circuit is under pressure.

He starts the A/C system and notices that the pressure drops.

He turns off the A/C system and adds DYE. Then he searches leaks with an UV lamp. After 10 minutes, no leak is found.

The operator offers to recharge the system and to come back when the system does not provide cooling in order that he can locate the leak.

Operation cost: 102.50 $

Garage number: 27 ***Date:*** 03/07/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

This garage includes two technicians.

The operator pushes the Schrader twice. Then he checks the air temperature and the compressor clutch.

He connects the RRR group (Robinair Smartcart) to the HP and LP SVs via a manifold. He emptied the circuit by releasing all the gas to the atmosphere.

Once the circuit is evacuated, he prepares the DYE can installed on the LP of the RRR group, then he reads the manufacturer charge and charges the system with 1.5 lb of R-134a.

He does not perform leak search and do not recommend me to stop by a few days later to check refrigerant leaks.

Operation cost: 124.60 $

Garage number: 28 ***Date:*** 03/08/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

Three operators work in the garage.

The operator in charge of the Montero checks the compressor clutch, and then the temperature of the air blown.

He connects the automated RRR group (SPX ROBINAIR Cool tech 3400Z) to the HP and LP SVs in order to check the pressures (with the A/C on and the A/C off). Then he puts the circuit under pressure using CO_2.

A first leak search is performed with water and soap. No leak is found.

He empties the system by releasing its content (CO_2 + R-134a) to the atmosphere.

He connects another automated RRR group (White industries 6R system). Using this group, he evacuates the system, adds some DYE and recharges with R-134a. He turns on the car engine and the A/C system during at least 30 minutes, and performs a new leak search using an UV lamp and ad hoc eyeglasses.

The same operating mode will be applied to a camping car belonging to another customer (use of CO_2 to put the system under pressure, and release of the system content to the atmosphere).

To complete the operation, he adds a label on the engine chassis indicating the name of the garage, the date, the refrigerant type, and the charge.

At the end, he recommends me to use the A/C several weeks and to come back to check the leaks using DYE.

Operation cost: 68.64 $

***Garage number*: 29 *Date:* 03/08/08 *Vehicle*: Mitsubishi Montero**

Operation description

Three technicians work in this garage.

The operator in charge of the car checks HP and LP pressures, and the temperature in the cabin.

He connects the automated RRR group to HP and LP SVs.

He does not recover the refrigerant. He adds DYE, tops up the refrigerant charge and performs a leak search with an electronic leak detector.

No leak is found.

He two options:
Either the system is left as is (recharge only 80 $)
Or he does refrigerant recovery, evacuates the system, and then recharge, explaining that this will remove moisture in the circuit (140 $).

I agree for the sole refrigerant recharge.

After the process, I have recovered 623 g.

The operator has also recommended coming back in a few weeks to check the leaks using an UV lamp.

Operation cost: 89.60 $

***Garage number*: 30 *Date:* 03/08/08 *Vehicle*: Mitsubishi Montero**

Operation description

There are about 4 employees in the garage.

The operator checks the compressor clutch, the HP and LP pressures, and the air temperature in the cabin.

He connects the automated RRR group to the HP and LP SVs. He recovers the refrigerant, evacuates the system, and recharges the refrigerant. He also adds DYE.

Then using an electronic leak detector he performs a leak search during less than 10 minutes. No leak is detected. He recommends stopping by in a few days to check leaks with the DYE.

Operation cost: 52.33 $

Garage number: 31 **_Date:_** 03/08/08 **_Vehicle_**: Mitsubishi Montero

Operation description

This garage includes three technicians.

The operation mode is as follows:

- Checking of air temperature
- Gas analysis by connecting an analyzed to the circuit LP SV
- Connection of an automated RRR group to the HP and LP SVs. Control of HP and LP pressures (the A/C system is OFF)

He performs the recovery, then evacuates the system, and recharges. He adds oil and DYE using the RRR group.

The leak search is performed using UV lamp and he wears eyeglasses. The leak search duration is performed during about 10 minutes. No leak is found.

He recommends stopping by in one or two weeks to perform a new leak search.

Operation cost: 87.41 $

Garage number: 32 **_Date:_** 03/08/08 **_Vehicle_**: Mitsubishi Montero

Operation description

There are three technicians in this garage.

The operator offers me refrigerant recharge and leak search using DYE.

He connects the automated RRR group to HP and LP SVs and checks the HP and LP (A/C system ON, then OFF).

He empties the circuit releasing all to the atmosphere. Then he evacuates the system. He adds DYE and then recharges without looking at the manufacturer label indicating the nominal charge.

He says that he recharged 2 lbs of refrigerant.

He does not perform leak search. He recommends me to come back in a week if the A/C system does not operate adequately. He also mentions that it is usual to recharge refrigerant every year.

Operation cost: 95.00 $

Garage number: 33 ***Date:*** 03/10/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

4 technicians work in this garage.

The operator is equipped with one manifold, one cylinder (30 lbs), and one vacuum pump.

First, he checks HP and LP (A/C ON and OFF).

Then, he releases the remaining content of R-134a to the atmosphere.

He evacuates the system and waits for about 10 minutes in order to check is the pressure raises.

He disconnects valves of HP and HP SVs and realize that they leak (the circuit is still evacuated). So he decides to replace them.

Once he has found new parts, he installs them, prepares a DYE can and recharges directly (without evacuating the system).

He reads the nominal refrigerant charge indicated by the manufacturer.

He recommends me to come back in a week of two to perform a leak search.

Operation cost: 140.00 $

Garage number: 34 ***Date:*** 03/110/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

This medium-size garage employs two technicians and one manager.

The operator checks the HP and LP (A/C system ON, then OFF) using an automated RRR group (ROBINAIR SPX).

He recovers and recycles directly the refrigerant, evacuates the system, adds DYE and recharges the system.

He performs leak firs with an electronic leak detector (during 20 min) then with an UV lamp (during more than 10 min).

He checks leaks at the evaporator by opening the access located on the passenger side. He checks also the condenser fittings, which needs to undo the plastic protection (he is the only one who did that).

He is doubtful on the tightness of the Schraders and so he decides to replace them.

Once again he recovers the refrigerant, he replaces the valves, evacuates the system, and recharges 1.5 lb of refrigerant.

He checks very quickly the tightness of valves. He also checks that the A/C system runs smoothly by controlling pressure and temperature.

He does not make any recommendation.

Operation cost: 157.05 $

Garage number: 35 ***Date:*** 03/11/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

The garage is small and there are two technicians.

The operator checks the gas nature by connecting an analyzer to the LP SV of the system. He connects an automated RRR group (ROBINAIR) to HP and LP SVs.

He starts the car engine and the A/C system. He checks the air temperature at the blowing outlets. He also checks service pressures.

He starts the refrigerant recovery, evacuates the system (test under vacuum during about 15 min) and recharges after he has read the manufacturer nominal charge.

Once the system is recharged, he checks again the temperature in the cabin and service pressures.

He adds some more refrigerant.

After some additional checks (pressure/temperature), he performs leak search with an UV lamp and the ad hoc eyeglasses, during about 10 minutes.

No leak is found. Maybe the leak is too small.

He does not recommend coming back for a new leak search.

Operation cost: 124.08 $

Garage number: 36 ***Date:*** 03/12/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

4 people work in this garage.

The technician in charge of the vehicle connects an automated RRR group (ROBINAIR Cool tech 341342 SPX). He looks neither at the compressor clutch nor does he check the air temperature at the blowing outlets.

He checks very rapidly the pressures; the car engine and the A/C are ON. Then he starts the refrigerant recovery.

The recovery lasts about 10 minutes, and he evacuates the system for 15 min. Evacuation is maintained for about 15 additional minutes to check the leak tightness of the system.

Then he charges oil. The oil is injected by pushing on a button. The level of injected oil is controlled at the oil tank behind the automated group.

He charges the refrigerant in the system. The recharge starts with the car engine OFF, then the car engine and the A/C system are turned ON to finish the recharge. He will charge 2 lbs.

Leak search is performed during about 2 minutes, using an electronic leak detector. He does not check the whole circuit.

He checks the temperature in the cabin and service pressures.

Operation cost: 187.38 $

Garage number: 37 ***Date:*** 03/12/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

Three technicians work in the garage.

The operator in charge of the vehicle checks the air temperature at the blowing outlets, and the compressor clutch.

He connects the automated RRR group and check pressures (A/C system ON, then OFF).

He checks rapidly the system with a lamp.

Diagnosis: the circuit is under pressure, so there is refrigerant in the circuit. It seems that the A/C system has never been serviced.

He recommends refrigerant recharge.

He recovers the refrigerant, evacuates the system, and recharges 1.8 lbs of refrigerant.

No leak search is performed. No DYE is added.

Operation cost: 163.25 $

Garage number: 38 ***Date:*** 03/12/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

This garage is large with at least 5 technicians.

As soon as the technician takes the vehicle in charge, he connects an automated RRR group (ROBINAIR Cool tech 700) to the system.

He recovers the refrigerant, evacuates the system, and recharges refrigerant.

He performs a leak search with an electronic leak detector.

I have not been able to see much more, since very gently I am requested to leave the working area with regards to liability and insurance.

Operation cost: 97.66 $

Garage number: 39 **_Date:_** 03/13/08 **_Vehicle_**: Mitsubishi Montero

Operation description

In this garage, I am not allowed to stay in the operation area because of insurance concern. I can observe from about 10-m distance.

The operating mode of the technician is as follows:

- Check of the temperature of blown air
- Use of an automated RRR group and a manifold for the control of the HP and LP (A/C system ON, then OFF)
- Refrigerant recovery, system evacuation, check of the pressure raise when the system is evacuated (for 15 min), then addition of DYE and refrigerant recharge.
- Leak search with an electronic leak detector.
- No leak search with DYE

No recommendation concerning another visit or to go to another garage in the next weeks to check leaks with DYE.

Operation cost: 125.64 $

Garage number: 40 **_Date:_** 03/13/08 **_Vehicle_**: Mitsubishi Montero

Operation description

This garage is small with two technicians.

The operator turns the A/C SYSTEM ON. Using a lamp, he checks the circuit, and then he checks the compressor clutch engagement. Then he checks the air temperature at the blowing outlets.

He connects an automated RRR group (SNAP ON Eco 134) via a manifold. He measures service pressures. He adds DYE through the LP SV, using a pump. He performs leak search with an UV lamp and wears ad hoc eyeglasses. He finds traces of UV on the fitting between the two suction lines. He recommends replacing the seal.

The estimates for repairs is 204 $ all included.

Operation cost: NONE

Garage number: 41 **_Date:_** 03/13/08 **_Vehicle_**: Mitsubishi Montero

Operation description

Two technicians operate in this garage.

The technician in charge of my vehicle checks the compressor clutch and the air temperature at the blowing outlets. Service pressures are not checked.

He offers refrigerant recharge. He connects an automated RRR group (ROBINAIR SPX) to HP and LP SVs. He recycles the refrigerant, evacuates the system, and recharges.

No leak search is performed. No DYE has been used. He does not recommend checking leaks later on.

Operation cost: 70.00 $

Garage number: 42 **_Date:_** 03/13/08 **_Vehicle_**: Mitsubishi Montero

Operation description

Although the garage is very small, 4 technicians work there.

The technician in charge of my car checks successively: the temperature of blown air, the compressor clutch, and HP and LP pressures.

He offers refrigerant recharge, and next leak search.

He connects an automated RRR group and notices that the system is under pressure. He performs a leak search using an electronic leak detector. He does not find a leak. So he decides to recover the remaining refrigerant and evacuates the system. He leaves the system evacuated for more than 15 minutes. No pressure raise occurs.

He recharges with refrigerant, according to the nominal manufacturer charge as indicated on the label in the under hood. He had previously added DYE and oil.

Then he performs thoroughly a new leak search using an UV lamp (plus ad hoc eyeglasses) and an electronic leak detector.
He also checks the evaporator through the visit opening.

During the operation, he notices that the lines are clean compared to the other parts of the engine and tells me that the lines have probably been changed.

Operation cost: 106.55 $

Garage number: 43 **_Date:_** 03/14/08 **_Vehicle_**: Mitsubishi Montero

Operation description

The garage is large enough. There are six technicians. Service for A/C service check is 71.61 $.

When I arrive in the garage, one cap is missing on the LP Schrader.

The operator starts by a check of the system with a lamp.
He connects a gas analyzer to the LP.
The system is under pressure.
He injects DYE with a pump.
He connects an automated RRR group and checks HP and LP.
He tops up the R-134a charge in order to check leaks.
The leak search is done using an UV lamp and ad hoc eyeglasses.

After 10-min search (without check of the compressor, of the evaporator, or condenser fittings), he finds a leak on the most accessible fitting.

The repair estimate is 327.17 $. I do not agree to make the repair.

He recovers the refrigerant.

When I take the car, the A/C system is at atmospheric pressure. He does not mention the missing cap and this item is not mentioned in the quotation.

Operation cost: 91.03 $

Garage number: 44 ***Date:*** 03/14/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

The garage is small. Three technicians work there.

When I arrive, the system is empty (atmospheric pressure). He connects directly one R-134a cylinder via a manifold. No scale, no automated RRR group or leak detector (either electronic or UV).

He diagnoses that the circuit is empty and needs refrigerant recharge. The quotation is in the range of 100 $.

He starts the refrigerant recharge, without evacfuating the system. He turns ON and OFF the car engine and the A/C system several times. Also, he opens the cylinder, closes it, opens the manifold, and closes it. I have the feeling that he touches all valves without knowing well what he is doing. This behavior lasts about 20 minutes.

Then he disconnects the LP SV and release part of the charge to the atmosphere by pushing on the Schrader (may be he wants to purge air ???).

He recharges. He repeats what he did previously, and again he releases part of the charge to the atmosphere.

All together, this strange operation lasts at least 1h30min. Evidently something worries him. I start to become impatient. He stops operating, tells me that there is a problem without knowing what precisely. His explanations are fuzzy.

At the end, he says that I have not need to use the A/C system at this period of the year. He offers that I stop in another garage of his own, where an automated RRR group is available.

He requests 49.99 $ for the diagnosis, but what diagnosis ??!, and he adds that if I go to this his other garage the recharge will be free.

In addition, he has lost the cap of the HP SV.

When I get the car back, the circuit is still empty, at the atmospheric pressure, same as when I arrived few hours earlier.

Operation cost: 49.99 $

Garage number: 45 **_Date:_** 03/14/08 **_Vehicle_:** Mitsubishi Montero

Operation description

There are 4 technicians in this garage.

The A/C system is empty with air inside.

The operator checks the compressor clutch and the temperature of the blown air.

He connects an automated RRR group (Macto Tools) and evacuates the system for 20 minutes.
Then he disconnects the group to connect a manifold and one cylinder of brand new refrigerant. He opens valves to charge via the LP SV.

He asks me to start the car engine and to turn the A/C system ON to complete the charge. He looks at service pressures regularly.

I notice regular compressor cycling (ON/OFF regular every 30 seconds approximately).

He charges with refrigerant without knowing how much he is charging.

Note:
A garage has already mentioned to me, a few days before, about the compressor cycling. He had recommended replacing the thermostat. Looking at the HP and LP pressures, I wander if there was not a circuit clogging because of the large number of charges with DYE and oil. So I dismounted the most accessible line (the compressor suction line) to check the circuit. The line was full of DYE and oil. Consequently I cleaned the circuit, which means disassembly of all lines (2 compressor suction lines, 3 liquid lines, the HP liquid receiver, the discharge line). After the system has been evacuated, the compressor cycling is still there. Conclusion, the compressor cycling is really caused by the thermostat default.

Operation cost: 70.00 $

Garage number: 46 ***Date:*** 03/15/08 ***Vehicle*:** Mitsubishi Montero

Operation description

This garage is the smallest one I visited during the campaign.

When I arrive, the system is empty (full of air at atmospheric pressure). Caps on the HP and LP SVs are missing.

The operator checks the temperature of air blown.
He connects rapidly a manifold and one R-134a cylinder and starts the refrigerant charge. He turns the car engine ON, and also the A/C system. He does not open the HP valve of the manifold and so he can only see the LP.

The compressor cycling starts (ON/OFF every 10 seconds). He continues the refrigerant charge looking at the LP.

Several times he turns the engine OFF and then ON. He is perplex, looks at the compressor, and checks the circuit… This lasts for more than 40 minutes.
Finally, he forces the compressor clutch engagement by connecting it directly to the battery. Two minutes of operation and then the big problem. All at once, the compressor rejects refrigerant. The HP safety valve has been opened during few seconds (no evacuation and thus there are non condensables in the HP).

The operator who was in the car has been surprised and turned the engine OFF immediately.

His diagnosis is as funny as the situation: he says that there is a leak on the suction line and that there should be a problem with the compressor.

Conclusions
The quotation for replacement of the suction line is 220 $. He recommends changing the compressor.

I had to pay 45 $ for the service.

I have recovered 495 g of refrigerant from the system.

The system remained empty, open to air.

Operation cost: 45.00 $

Garage number: 47 ***Date:*** 03/15/08 ***Vehicle*:** Mitsubishi Montero

Operation description

This garage is better organized than others. More than 6 technicians work in it.

The operator connects an automated RRR group (ROBINAIR). He looks at the system pressures and the equipment operates by itself (recovery, evacuation, and recharge).

The operator adds DYE and oil, but he does not perform any leak search. He does not even mention the missing caps on HP and LP SVs.

The bill is 201 $

Operation cost: 201.41 $

Garage number: 48 ***Date:*** 03/16/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

Two technicians work in the garage.

The operator in charge of the car checks the compressor clutch. He sees that it does not engage. He recommends to evacuate the system, and to recharge the system with the manufacturer nominal charge that he reads on the under hood. He says that 2 12-oz small cans are necessary for the recharge and that DYE will be added to search leaks.

I have a look around the garage and noticed that there is no automated RRR group.

The quotation is 97.32 $ including refrigerant recharge and leak search. There is no customer in the garage, but he has no time to take care of the car …

I validate this garage because he is among garages that use small cans.

Quotation cost: 97.32 $

No operation

Garage number: 49 ***Date:*** 03/16/08 ***Vehicle*****:** Mitsubishi Montero

Operation description

The system is still empty. Similarly to the previous garage, the operator remarks quickly that the clutch does not engage.

During several minutes he is going to try shunting the clutch contact by connecting it directly to the battery.

I do not understand what he is doing. After 20 minutes, he says that the compressor does work and he recommends to change it.

He contacts a supplier and tells me that the price for the compressor is 650 $.

To this price, it has to be added 60 $ for the R-134a recharge and 150 $ for manpower.

Again a no sense diagnosis.

Operation cost: 30.00 $

Garage number: 50 ***Date:*** 03/16/08 ***Vehicle*:** Mitsubishi Montero

Operation description

4 technicians work in this garage. The system is still empty.

He turns the car engine ON and also the A/C system. As the previous technicians, he notices that the clutch does not engage. He offers to recharge the system and check leaks.

The operator connects the system to a manifold to the HP and LP.

He looks at pressures. Without much thought, he starts charging the system (no evacuation of the system).
This time, the compressor cycling is less rapid than previously (about every minute).

The operator charges in gas phase without looking at the quantity he is charging. I understand that he does not know anything about pressures.

Several times, he goes inside the car to check if the air blown is cold.

He seeks advice from another technician, who tells him to add oil. He goes to the end of the garage and picks up one 12-oz can.

He connects a clamp in place of the original can (leaks) and S&C a new can. He charges some liquid refrigerant. Without knowing if the can is empty, he disconnects the can, which releases its content to the atmosphere. Moreover, this can does not contain oil.

For the leak search, he uses a usual lamp without any specific equipment to detect DYE (which has not been charged in the system anyway). He finds a leak at the condenser.???

He recommends to replace the condenser for 400 $ including parts and manpower.

Conclusion: **I paid** 100 $ for the refrigerant recharge.
I have recovered 772 g.